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INSTITUTION OF STRUCTURAL ENGINEERS

Concrete and Structural Form

By Professor P. L. Nervi

Portal Frame Analysis by Moment Area Methods

Written Discussion on the Paper by Mr. J. F. Horridge

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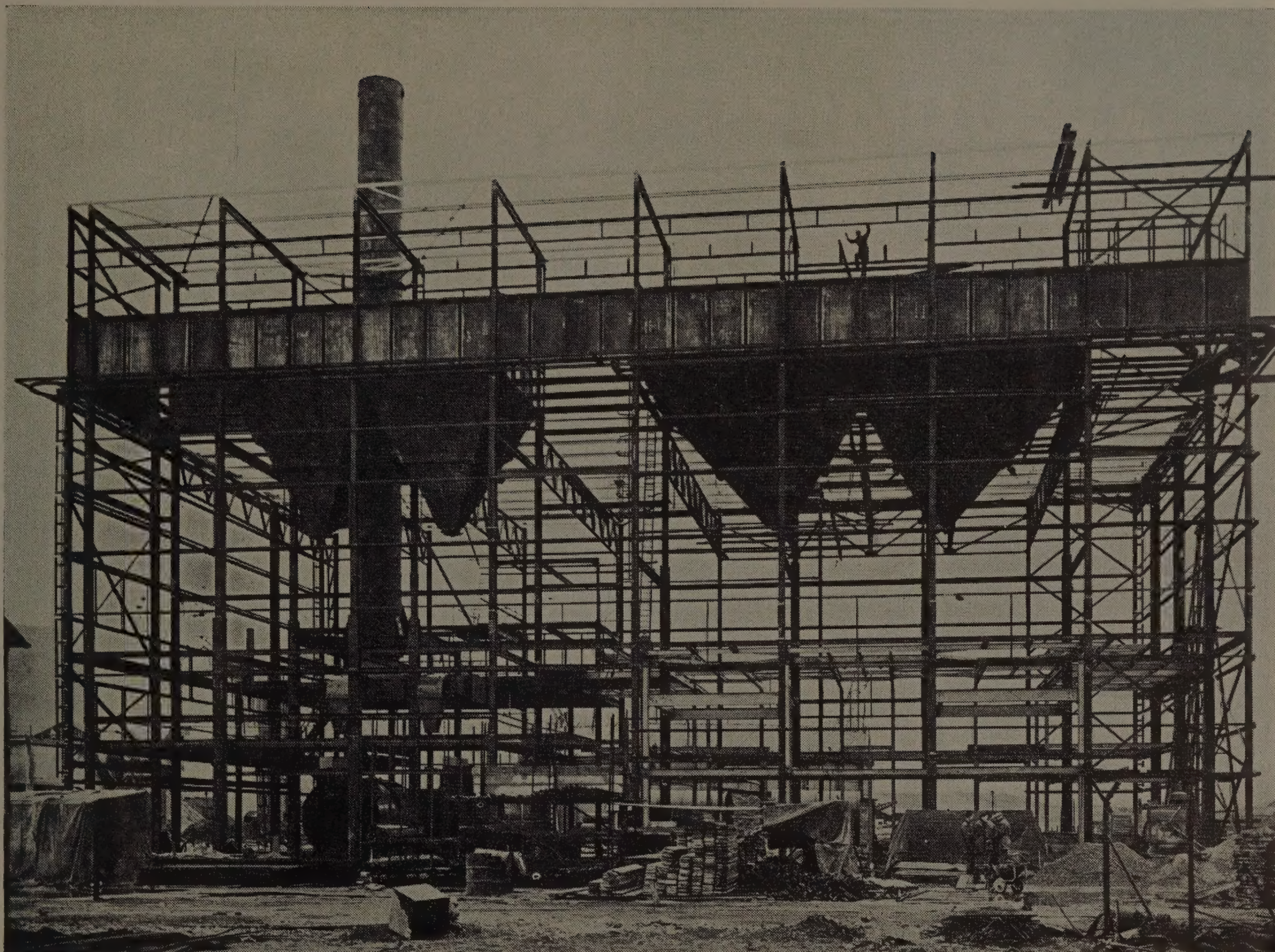

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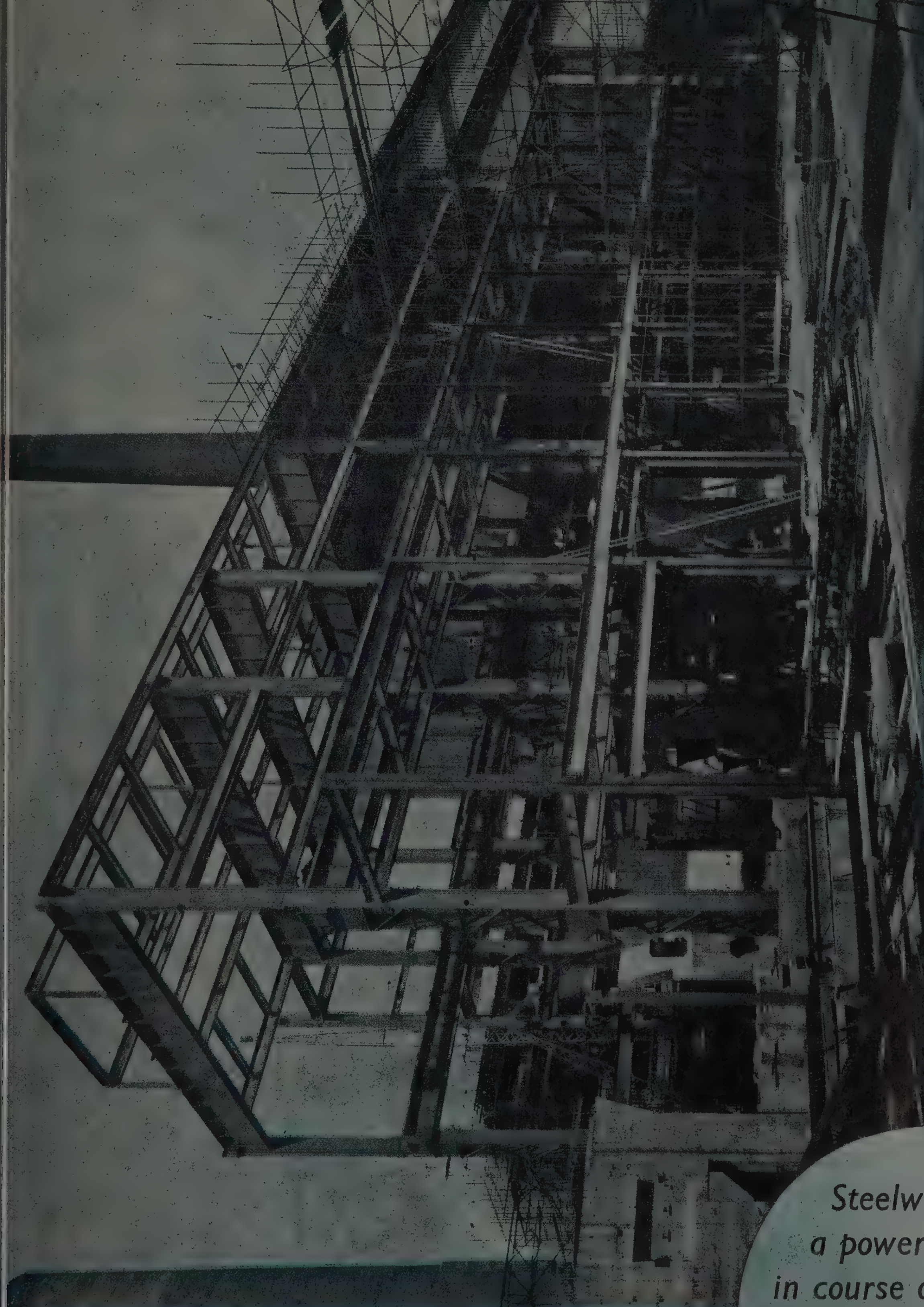

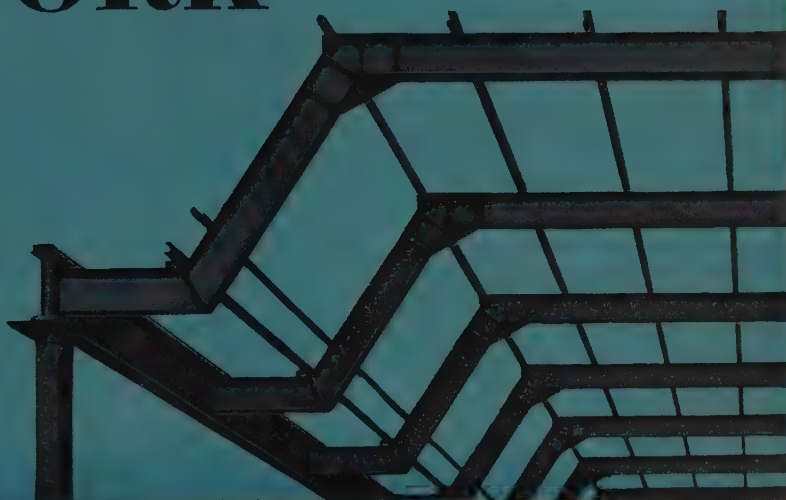

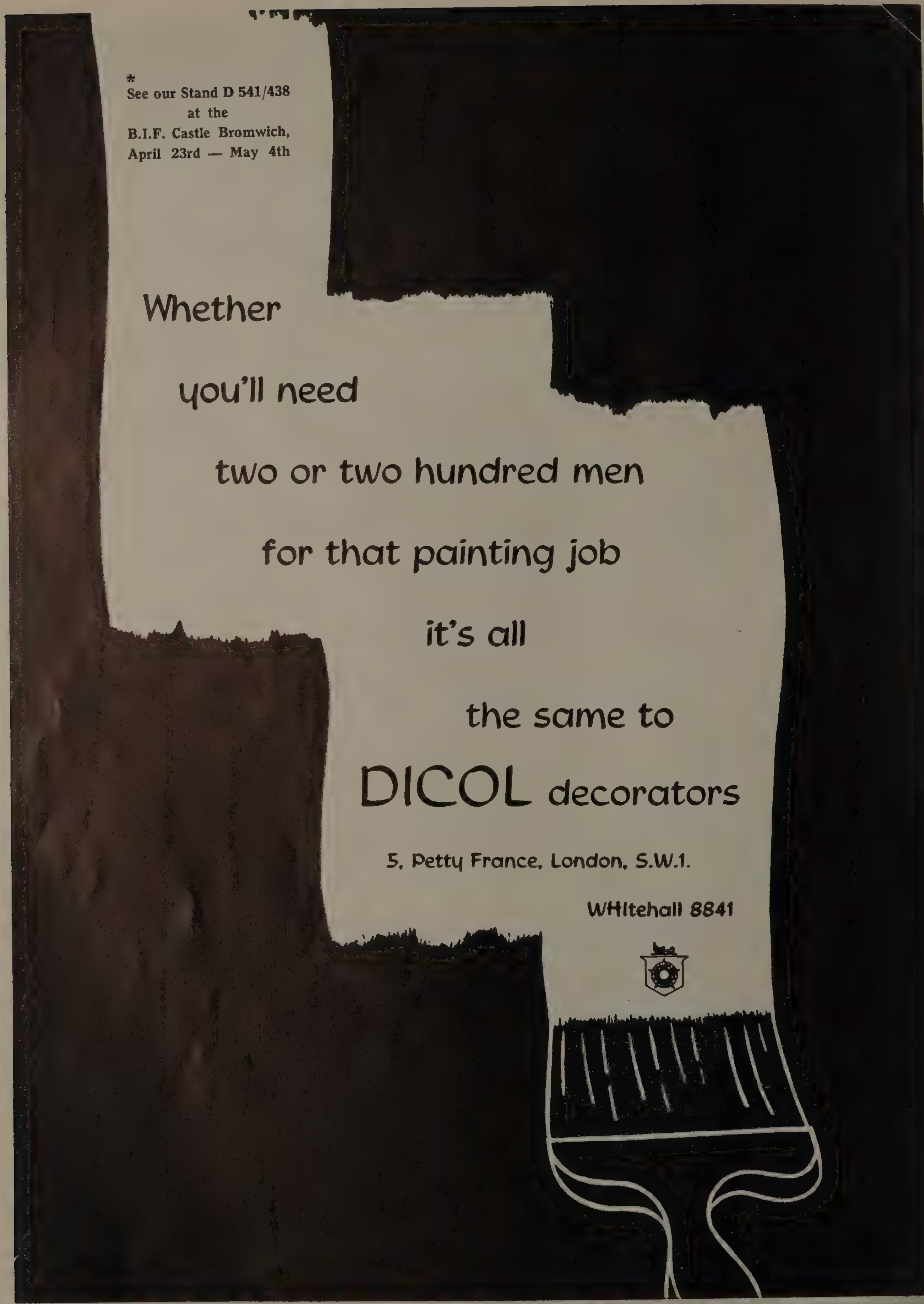
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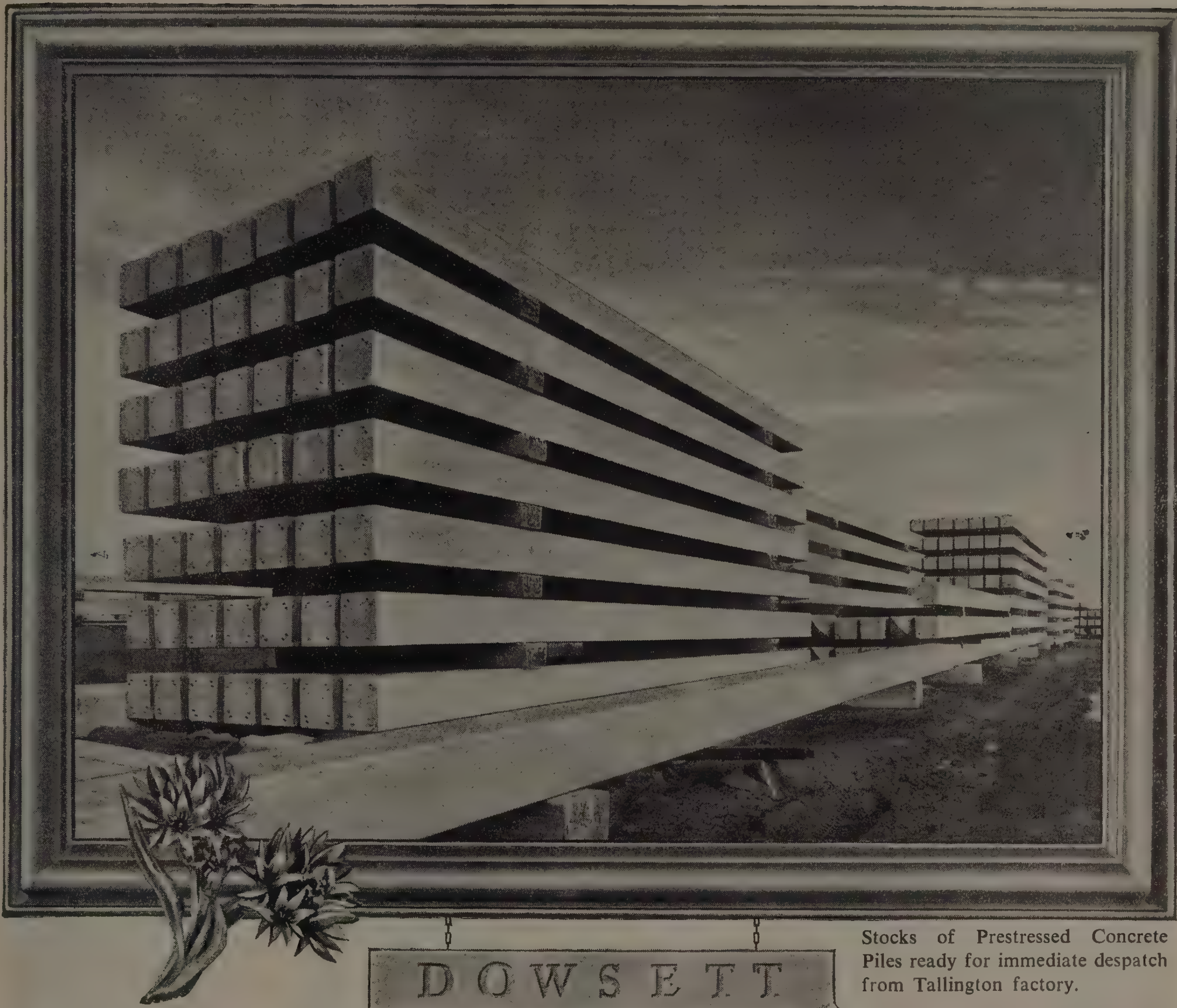

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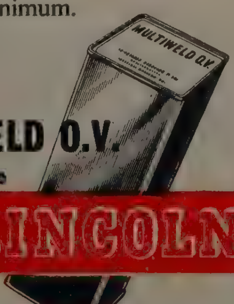

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Concrete and Structural Form*

By Pier Luigi Nervi

I am very honoured and deeply grateful for this opportunity of meeting my English colleagues and of talking to them about some of the work I have done in the course of an already long career as designer and constructor.

I should make it clear that I both designed these works and was responsible for their construction as partner and technical director in the firm who built them. And I must say, also, that this opportunity of uniting these two aspects of the construction process—design and execution—which have tended more and more to separate into two distinct functions, has greatly contributed to any success I may have achieved.

The fact that design and actual construction could be united in this way was due to the method of placing contracts, known as the "competition-tender," which is already fairly widespread and is tending to be increasingly used in Italy. The method consists in inviting a number of firms, known to be well qualified from the technical point of view, to submit a tender including the actual design as well as a price quotation. The design is based on an outline provided by the commissioning authority and these outlines always allow ample freedom for the best architectural and structural solutions to the problem. Design and tender are sent in as in all normal competitions of this kind. The commissioning authority makes separate examinations of the technical and the economic data and selects the design which seems the most satisfactory from all points of view.

A design that is good from the aesthetic and technical points of view is nearly always sufficiently economical; in any case, the commissioning authority has full data on which to base a choice and may even accept a tender which is not the lowest, if the qualities of the design are such as to outweigh a small difference in cost.

In some cases, the invitation to tender asks for a lump sum contract, so that, except for unforeseen circumstances, the commissioning authority knows exactly how much the finished work will cost.

The advantages of such a system are obvious. Competition stimulates the designer-contractor to develop the most suitable design from the economic as well as from the technical point of view, and to study new and more efficient building methods for its execution. The extensive knowledge of materials which he possesses as a practical contractor, his realization of the limitations and difficulties of the actual execution and his study of means of overcoming them will, on the one hand, ensure a realistic approach to the design, but they may also suggest daring, yet rational, solutions that might have seemed impossible to the purely professional designer.

Fig. 1.—Sports Stadium, Florence

Moreover, the designer-contractor can carry out preliminary tests and experiments—even quite costly ones—within his own organization, where this would be practically impossible for the purely professional man.

It seems to me necessary to make these points clear, in order to emphasize what I consider the most important characteristics of my works—that they are the result of a constant endeavour to find the most efficient design from the technical and the economic point of view. All my designs, even those that might seem to have been developed on more formalistic lines are, therefore, the direct result of structural or constructional considerations.

Moreover, I am deeply convinced—and this conviction is strengthened by a critical appraisal of the most significant architectural works of the past as well as of the present—that the outward appearance of a good building cannot, and must not, be anything but the visible expression of an efficient structural or constructional reality.

In other words, form must be the necessary result, and not the initial basis, of structure.

The first important work which my firm was commissioned to carry out was the Stadium for the City of Florence, built in 1927.

The outline given by the City's Technical Department was very sketchy; it specified the number of spectators that the stadium should hold (35,000), the dimensions of the covered grandstand, the length of the running track, the provision of a Marathon tower and a few more details of a general nature.

**Paper read before a Joint Meeting of the Institution of Structural Engineers, the Cement and Concrete Association, the Prestressed Concrete Development Group and the Reinforced Concrete Association at the Friends' Meeting House, Euston Road, London, N.W., on the 14th October, 1955. Mr. Stanley Vaughan, BSc., M.I.C.E., M.I.Struct.E., A.C.G.I., M.Soc.C.E.(France). (President of the Institution of Structural Engineers) in the Chair.*

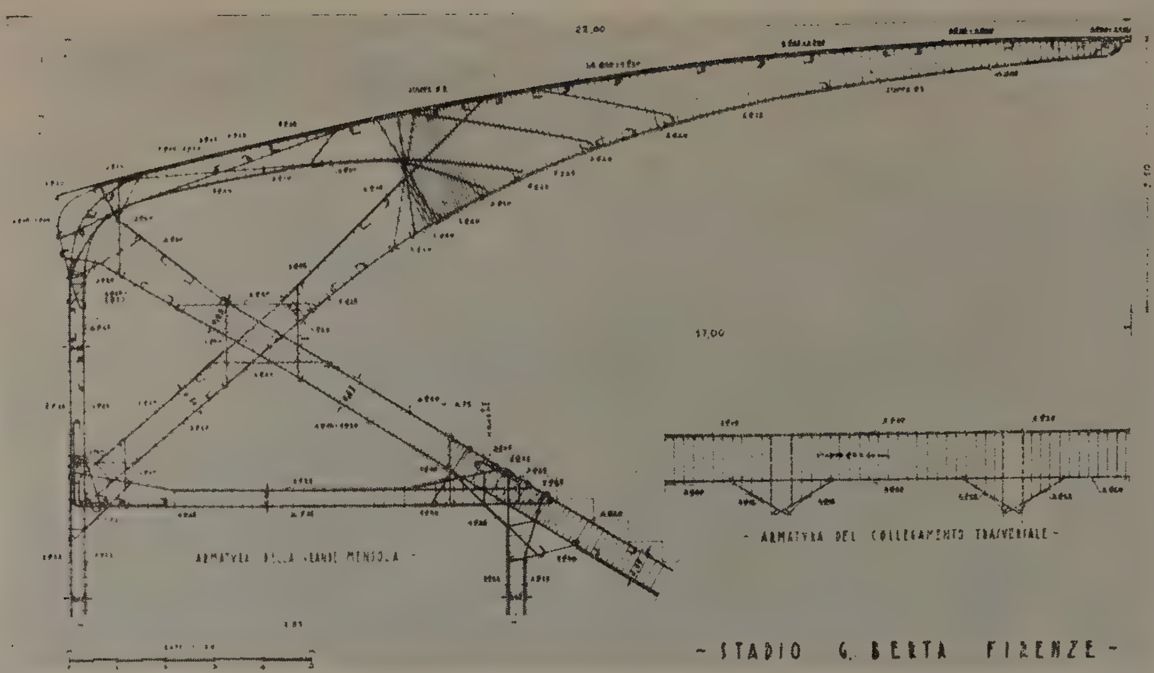


Fig. 2.—Sports Stadium, Florence. Structure of the covered stand

Fig. 3.—Sports Stadium. Concrete Staircase

Essential items, from the architectural and economic point of view, were the design of the wide-span canopy to the grandstand, the open stands, the external staircases and the Marathon tower.

The principle of the design for the covered stand is obvious. It provides for the equilibrium of the whole structure without ground anchorage ; these anchorages are always uneconomical because they involve the use of large quantities of material to counteract the forces transmitted from the anchorage to the ground, through the structure.

The variation in section of the main ribs is determined by the law governing the variation of moments.

Purely aesthetic considerations inspired the slight curve of the canopy and of the haunching of the main ribs.

An interesting problem was set by the outside staircases, which involved considerable difficulties in construction, and which made me realize, for the first time, the extent to which the full development of reinforced concrete is linked up with the problem of timber formwork and its inability to adapt itself to curving or spiralling surfaces.

I found the exact calculation of staircases impossible and I therefore broke down the calculation of this complex, statically indeterminate system in terms of simple, statically determinate elements, and calculated them for the greatest stability even at the cost of high unit stresses, as I was confident that the wonderful plastic qualities of concrete would of themselves bring about full and efficient monolithic action between the structural elements.

Events have fully justified my confidence, and the strictest acceptance tests and—more important—time and use, have demonstrated the perfect stability of the structure.

A particularly interesting opportunity was given to my firm in connection with the competition organized by the Italian Air Force authorities in 1935 for the construction of large hangars spanning 330 ft. by 135 ft. internally, with door openings of 165 ft. span.

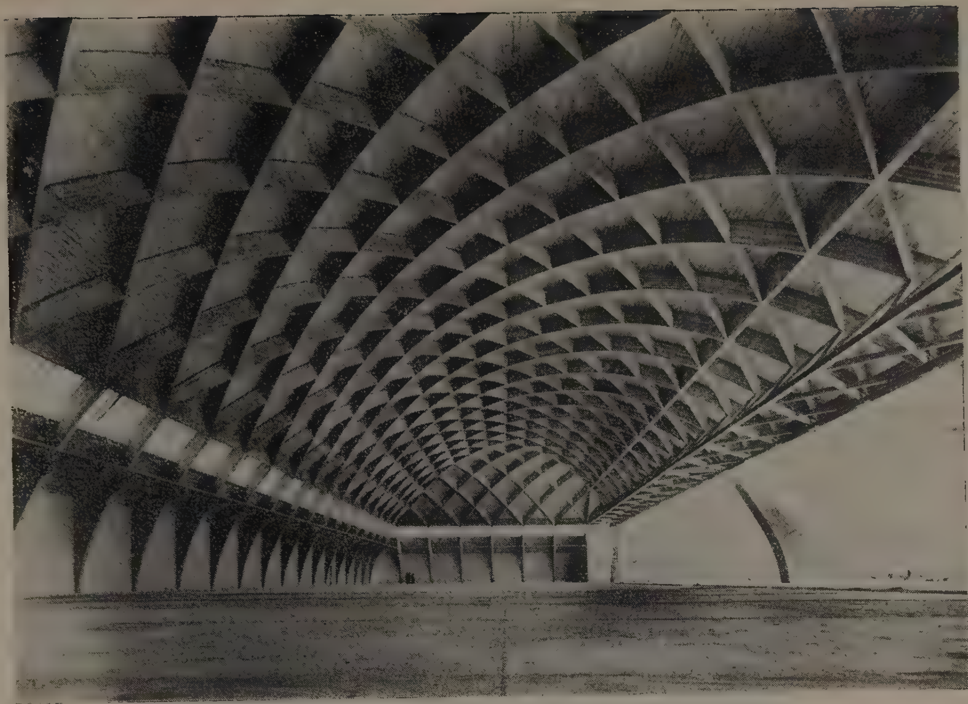


Fig. 4.—Aircraft Hangars at Orvieto (1938)

Fig. 5.—Aircraft Hangars at Orbetello (1942)

I designed the structure as a geodetic framework acting together as a whole, as I believed this would give the most economical solution and the one requiring the least steel.

With this type of design the theoretical calculations were extremely complicated and on a much larger scale than those for the spiral staircase I have previously mentioned. I therefore decided to make a preliminary calculation and then to make a detailed study of the stresses by means of experiments on a model.

The model experiments were carried out at the Milan Polytechnic, under the direction of Prof. Ing. Danusso

Fig. 6.—Aircraft hangars, precast concrete units in casting yard

and Prof. Ing. Oberti ; I believe this is one of the first instances in which the results of model tests have been applied to a really large-scale structure.

The results of the model tests enabled me to go fully into the static behaviour of the structure and to estimate the stresses in the whole framework, and it was found that the estimates provided by the preliminary calculations used in the construction of the model required hardly any alteration.

The actual construction was not easy, and provided yet another illustration of the economic disadvantages of timber formwork wherever reinforced concrete work goes beyond the simplest shapes.

In 1940 the Italian Air Force authorities invited new tenders for the construction of hangar No. 6, of similar dimensions. At that time, the need for economy in materials and timber had become even more acute and this is why, on the basis of the experience acquired, I decided to simplify and lighten the structure by designing the ribs as a lattice, which would enable me to make use of prefabrication. I also altered the system of supports in order to simplify the static system and make it more symmetrical.

In this case again, model tests were carried out. The greater structural simplicity and the extensive study made of the previous hangar design enabled me to make a still better approximate calculation, the results of which agreed exactly with those of the model tests.

The precasting of the units and their erection proved quite simple.

The method of assembly had been tested by my own firm, in its workshops, and by the Laboratory of the Milan Polytechnic. The joints were made by welding the steel and placing high strength concrete in situ in the space left at the junction of four units. The results were excellent, as may be observed on visiting the remains of the six hangars. The Germans destroyed them when they retreated by demolishing the supporting columns, but even after the fall of the roof, the great majority of the joints are still intact.

Meanwhile, conditions at the time had led me to work on a new type of construction that I called "ferro-cement." It is based on the principle of a very thin, highly reinforced slab obtained by forcing a very good quality cement mortar, made with cement and sand, through several layers of steel mesh and small diameter bars, joined together to form a section only a little thinner than the final unit.

The mortar was placed either by hand or by vibration and the results were extremely promising, not only because of the exceptional flexibility, strength and freedom from cracking of the slabs so obtained, but even more because the mortar being held by the mesh, one could greatly simplify the formwork or even do away with it altogether.

This new method was devised mainly for the quick and simple construction of small ships of a tonnage not exceeding 500 tons. In 1943, work was started on three motor-transport boats for the Italian navy and one sailing ship, with auxiliary power, for private industry.

The events of the war prevented the completion of this work, but in 1945 my firm built the yacht *Irene* which is still in use and in perfect condition, and in 1948 I adapted the method to build a 40 ft. yacht, the *Nennele*, for my personal use. The hull of the *Irene* is $1\frac{1}{2}$ inches thick, and that of the yacht *Nennele* $\frac{1}{2}$ inch thick.

These designs, and others, both for ships and buildings, which it would be too long to describe, gave me the necessary experience to attempt, in 1948, a much greater work—the roof of the Exhibition Hall at Turin.

In this case again, my firm was invited, along with several others, to submit a design and tender for the construction of a large exhibition hall, to replace the Palace of Fashion destroyed during the war.

The problem was particularly interesting, not only because of the dimensions of the hall (nearly 330 ft. span) but also because of the very short time allowed for the execution of the work, which was to start in

Fig. 7.—Concrete Yacht designed by P. L. Nervi

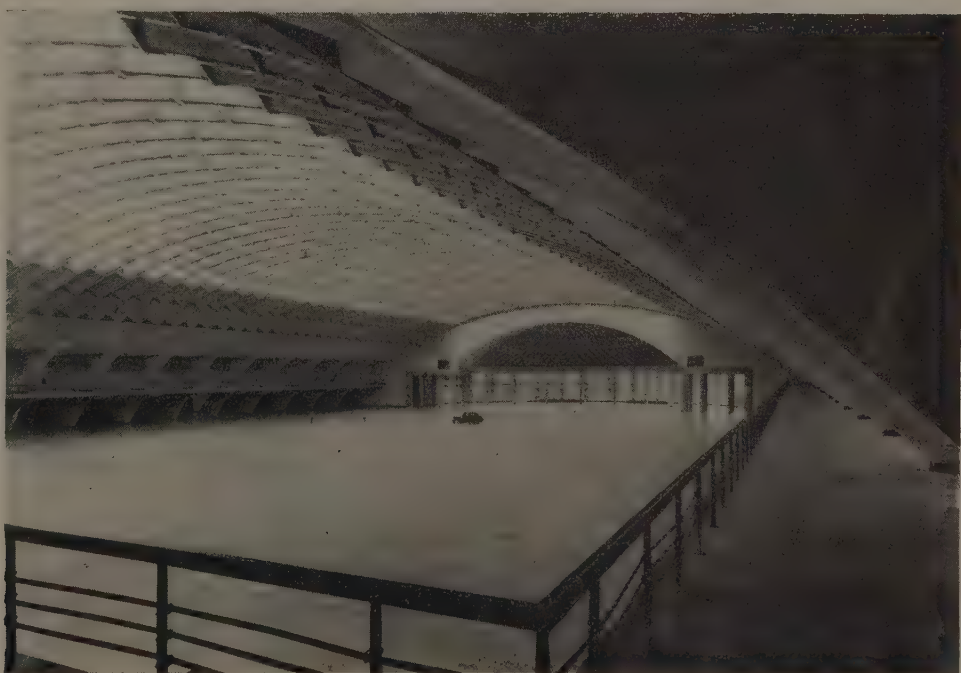


Fig. 8.—Exhibition Hall, Turin

September and had to be finished by the end of April. This very short time was a real problem in view of the difficult climate in Turin.

The solution I immediately thought of was a structure in corrugated "ferro-cement," which would attain the necessary stability by virtue of the corrugations and would enable us to use precasting, as in the case of the hangars, and to manufacture the roof units while the floors and supporting structure were being built.

On this basis I designed a roof structure with corru-

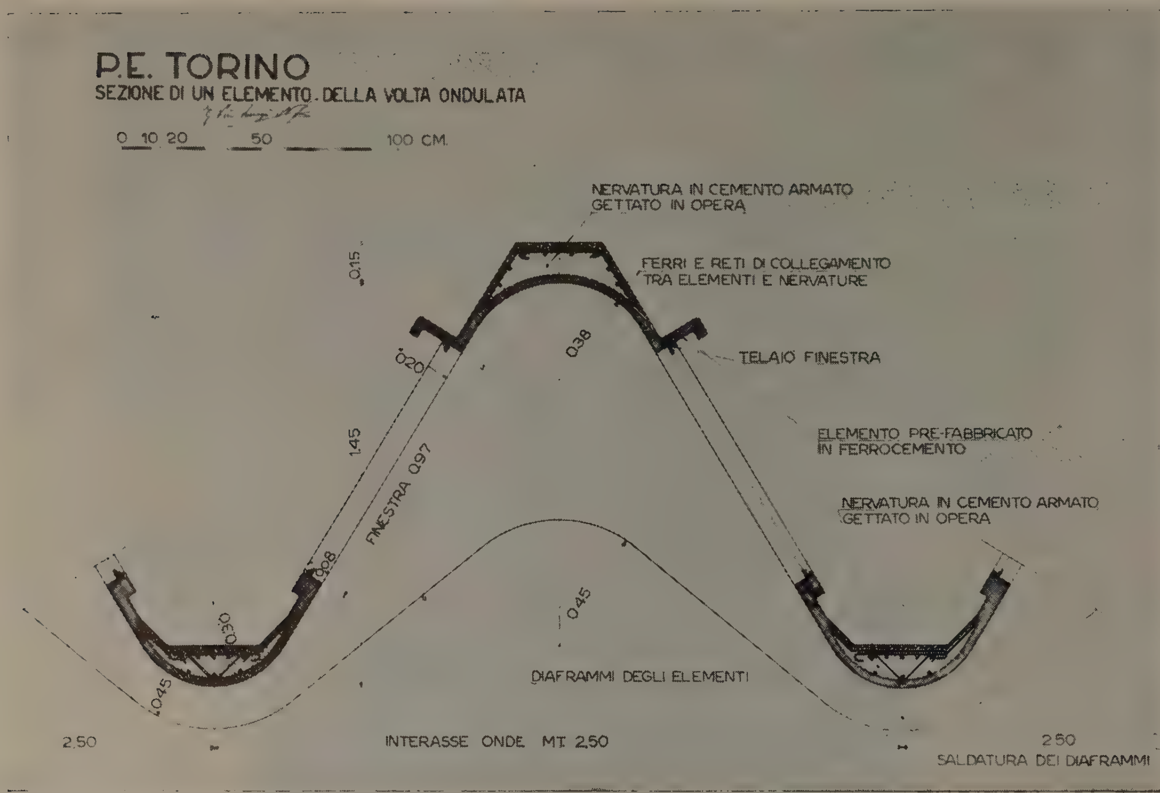


Fig. 9.—Exhibition Halls, Turin. Section of one of the Concrete Elements used in the Construction

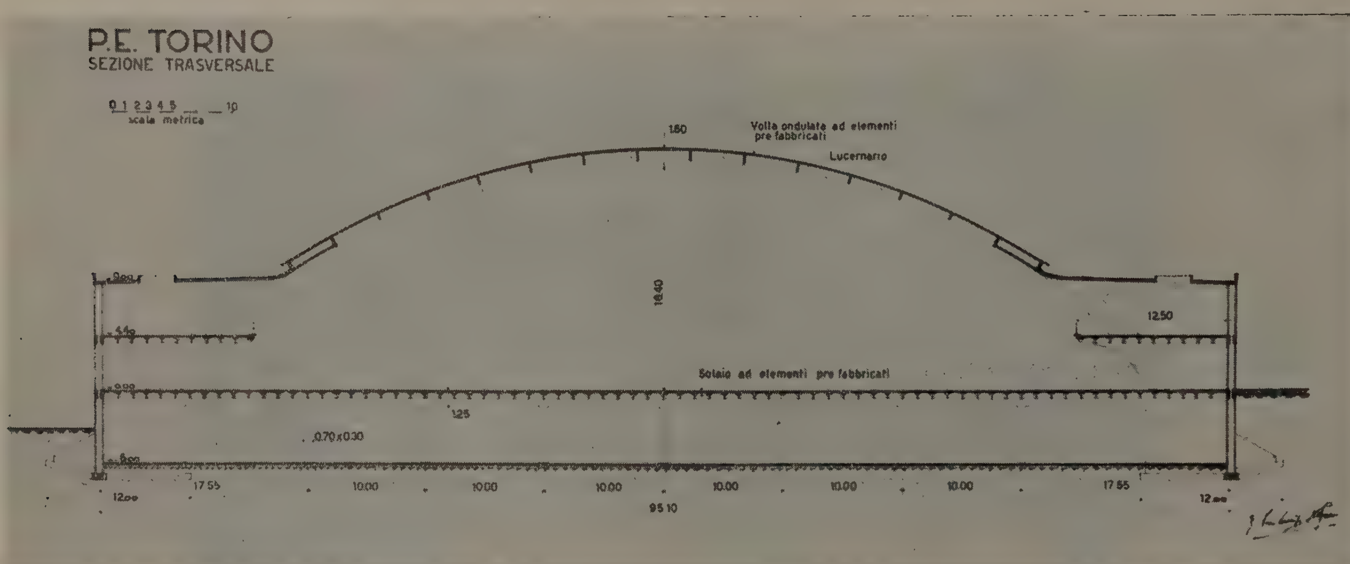


Fig. 10.—Exhibition Hall, Turin. Sectional View

gations of about 8 ft. span, divided into units about 13 ft. long. The units were to be made of "ferro-cement" in order to be as light as possible (thickness $1\frac{1}{2}$ inches) and would be rendered monolithic by reinforced concrete ribs cast in situ, and located at the peaks and troughs of the corrugations. In this way the "ferro-cement" units would act as junction units between the in situ ribs which in turn would take over the main structural work.

The units are closed at each end by stiffening diaphragms and adjacent units are joined together by a $1\frac{1}{2}$ inch thickness of mortar placed in situ.

The casting of the units proceeded without any difficulty and without the need for double formwork, as would have been the case with ordinary reinforced concrete.

Because of the richness of the mortar (800 kg. of best quality cement to 1 cu. m. of sand), the units could be demoulded in either two or three days, according to the outside temperature.

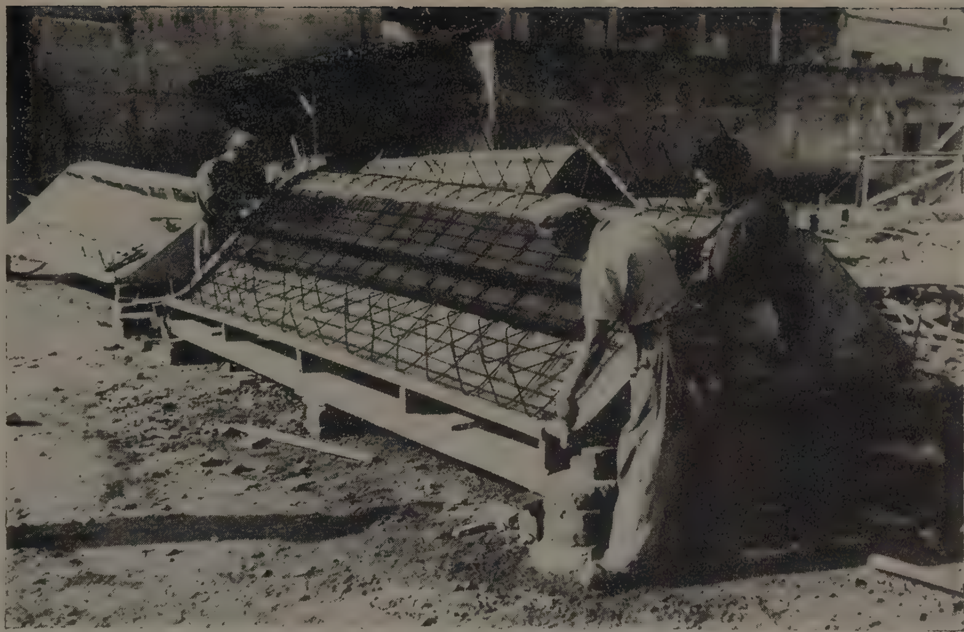


Fig. 11.—Exhibition Halls, Turin. Method of Construction Precast Concrete Unit

Fig. 12.—Section of the Exhibition Hall, Turin

Lifting and placing the units proceeded regularly and enabled about 3,230 sq. ft. of roof to be completed each day.

The construction took place in three stages, to get the fullest possible use from the movable scaffolding.

The corrugated roof was connected to the main supporting columns (which are at 24 ft. $7\frac{1}{2}$ in. centres) by fan-shaped "ferro-cement" units springing from inclined reinforced concrete elements.

The method of construction with precast corrugated

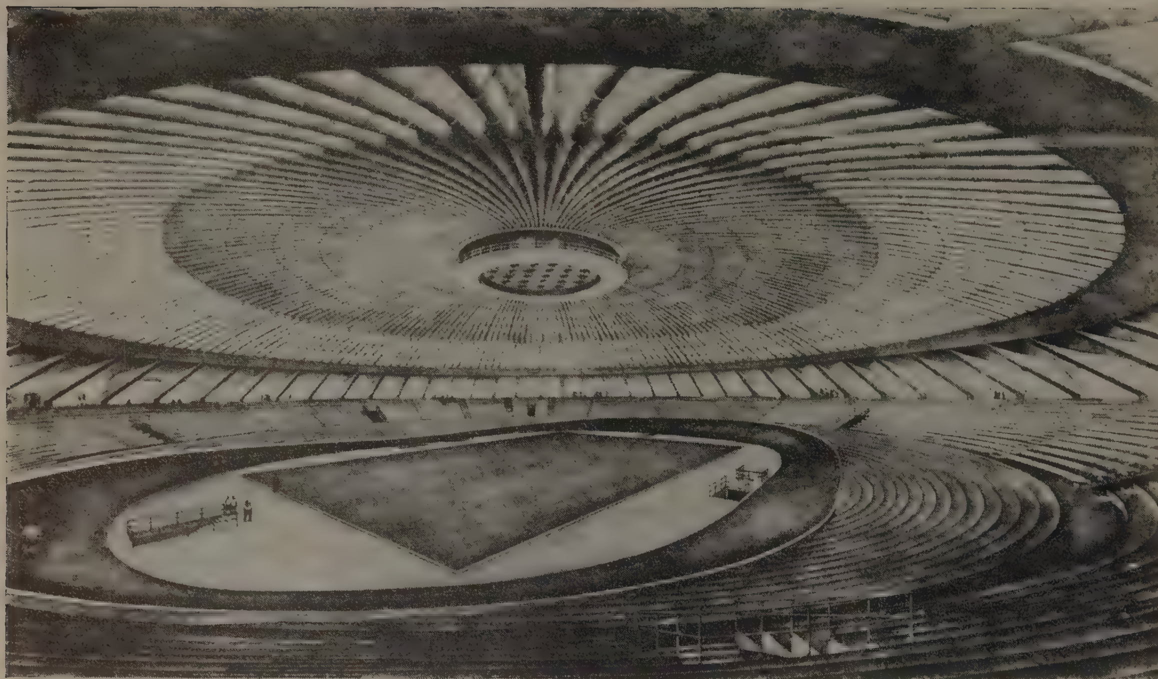


Fig. 13.—Project—Sports Palace, Vienna, Austria

" ferro-cement " units is readily applicable to the construction of large span domes and enabled me to solve the problem of the 420 ft. diameter roof for the Sports Palace at Vienna.

I made this design in collaboration with my architect son, Antonio, and entered it for the competition organized by the city of Vienna, but it was not successful.

It still has a certain interest, however, principally because it shows how the method can solve at one time all the various problems involved in the design of a roof with such a large diameter.

Quite apart from the essentially subjective judgment of its architectural aspect, which may or may not be found pleasing, a purely objective judgment will show how the problems of structural efficiency, economy, thermal insulation, provision for air-conditioning ducts, natural lighting and, more especially, acoustics and sound absorption (very important factors in large buildings) have all been simultaneously solved.

I have, moreover, often observed that a design that is sound structurally is generally satisfactory in every other way.

For the design of the 130 ft. diameter half-dome at the end of the main Exhibition Hall in Turin I used a method, based on precast units, which I had studied and actually used, though on small-scale structures, immediately after the war.

This method had also been inspired by the need for economizing in timber, which was extremely scarce in Italy at that time.

The method is suitable for the construction of vaults or domes and consists in filling the space to be covered with precast units measuring approximately 6 ft. 6 in. by 13 ft. The units are cast in concrete moulds which in turn are constructed on a model reproducing a section of the vault or dome to be built.

The edges of each unit are so shaped that when placed side by side they form channels about 4 in. wide between the units, which are filled with in situ reinforced concrete and form a network of supporting ribs that completes the structural system. The units are made of " ferro-cement " and are $\frac{3}{4}$ in. thick. During erection they are supported on scaffolding and require no actual formwork.

The units may be made in any shape and, provided allowance is made for the formation of the ribs, they lend themselves readily to the expression of any architectural form.

One year later, the organizing body in charge of the Turin Exhibition Hall asked my firm to submit another design and tender for a new hall, measuring 180 ft. by 540 ft. to be built close to the main hall.

Again, the time allowed for completion was very short as the work was to be started in November, and had to be ready before the end of March.

It was again necessary to use precasting, which could conveniently be carried out in the basement of the adjoining main hall.

My design was for a hipped vault, supported by four arches on a sloping plane with a slope corresponding approximately to the thrust of the vault.

For the construction of the vault, I decided to use the same method as for the half-dome in the main exhibition building, covering the required area with precast units placed in rows parallel to the angles of the roof and allowing for a strip of glazing round the edges to provide daylighting. To obtain this daylighting, the units in this part of the roof consisted only of the channels which formed the ribs.

For the surrounding flat-roofed portion, which spans 33 ft., I designed a system of corrugated beams in " ferro-cement," precast at the same time as the vault units. These beams are placed side by side and finished with a lightweight screed. Erection proved very quick and easy.

The beams in question are $\frac{3}{4}$ in. thick at the top, increasing to $1\frac{1}{2}$ in. at the soffit to provide room for the necessary reinforcement.

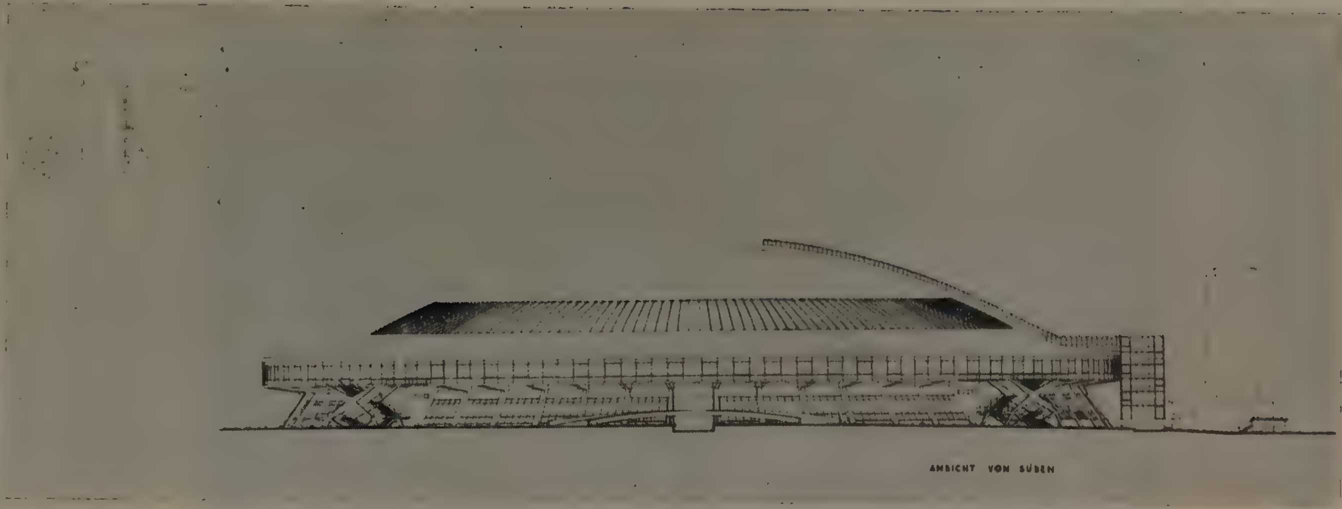


Fig. 14.—Project—Sports Palace, Vienna, Austria

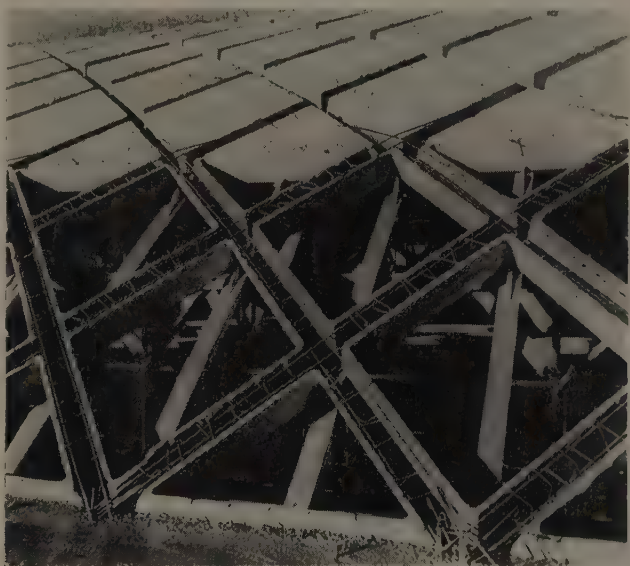


Fig. 15.—Exhibition Hall, Turin. Roof under construction

They were cast in concrete moulds which, in turn, had been made in a plaster mould. The visible underside of the beam, which is in contact with the form during casting, is perfectly regular and smooth, with a perfection of surface that could never be obtained by any of the usual finishing processes.

This method of construction is very adaptable ; I have used it many times for curved structures and always with excellent results.

An interesting application of precasting for the construction of vaults and domes is the design I made for the elliptical roof of the hall in the New Baths at Chianciano.

The elliptical plan complicated the problem and made it necessary to prepare formwork for half the roof, but here again the method proved most satisfactory, both as regards the quality of the work which it made possible, and as regards the saving in time as compared with in situ work.

A new method for the construction of roofs, based on "ferro-cement" moulds mounted on travelling scaffolding, movable both horizontally and vertically, which I designed in connection with an important competition, enabled me to free the construction of the ribbed roof from the restrictions imposed by timber formwork. This new freedom made it possible, not only to profile and position the main and secondary beams according to constructional convenience, but also to design roofs with ribs located along the isostatic lines of the principal bending moments, a design which makes possible strict adherence to the laws of statics and, therefore, makes the most efficient use of the materials.

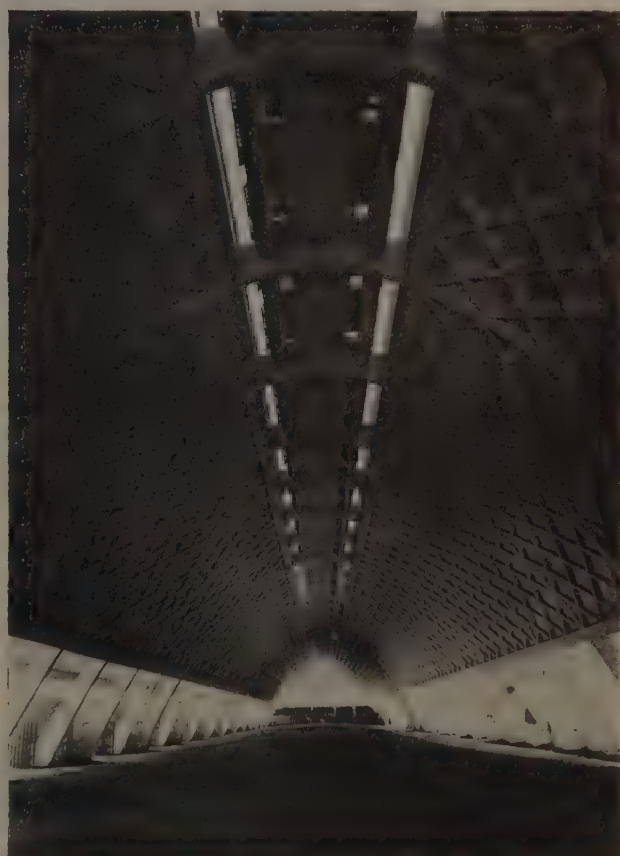


Fig. 16.—State Monopoly Salt Warehouse at Tortona

Fig. 17.—Exterior of the Ostia Kursaal near Rome

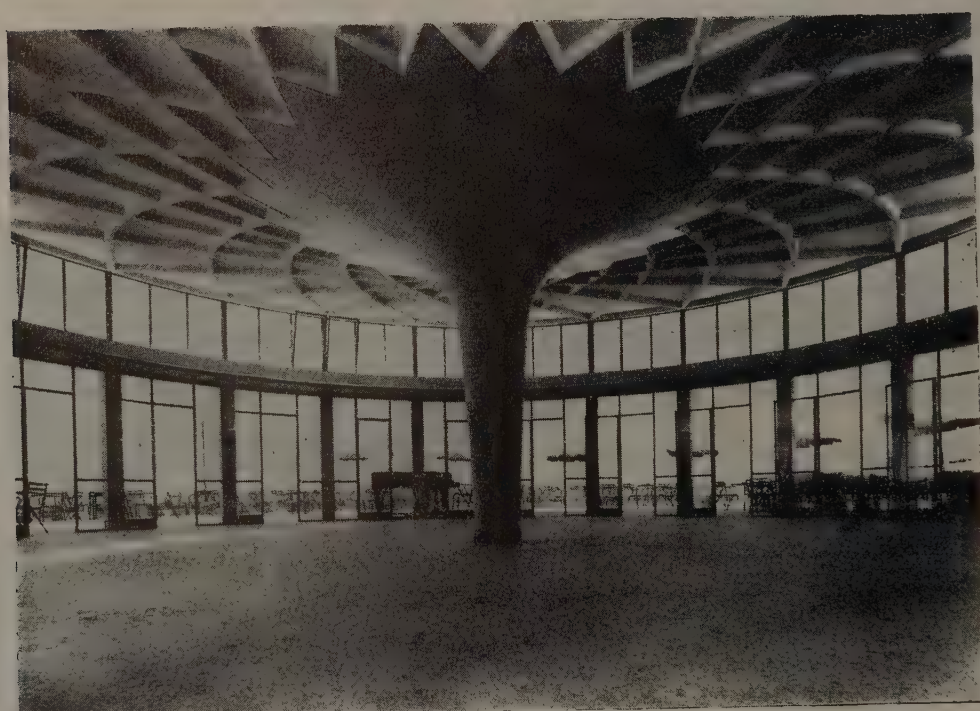


Fig. 18.—Interior at Ostia Kursaal, near Rome

It is interesting to observe the harmonious effect and the aesthetically satisfying result of the interplay of ribs placed in this way—a clear reminder of the mysterious affinity to be found between physical laws and our own senses.

These observations, you will notice, all point to the fundamental importance of purely constructional problems in the design of reinforced concrete structures. The buildings which I have had the pleasure of showing you would, in the main, have been impossible to build if the method of construction had not been studied from beginning to end as an integral part of the design.

I also want to emphasize that the full development of reinforced concrete, not only from the engineering, but also from the architectural point of view, is closely linked to a gradual liberation from the restrictions imposed by timber formwork, which in fact obliges the designer to conform to the pattern of timber construction, and is in direct opposition to the plasticity of form that is the most important structural and architectural

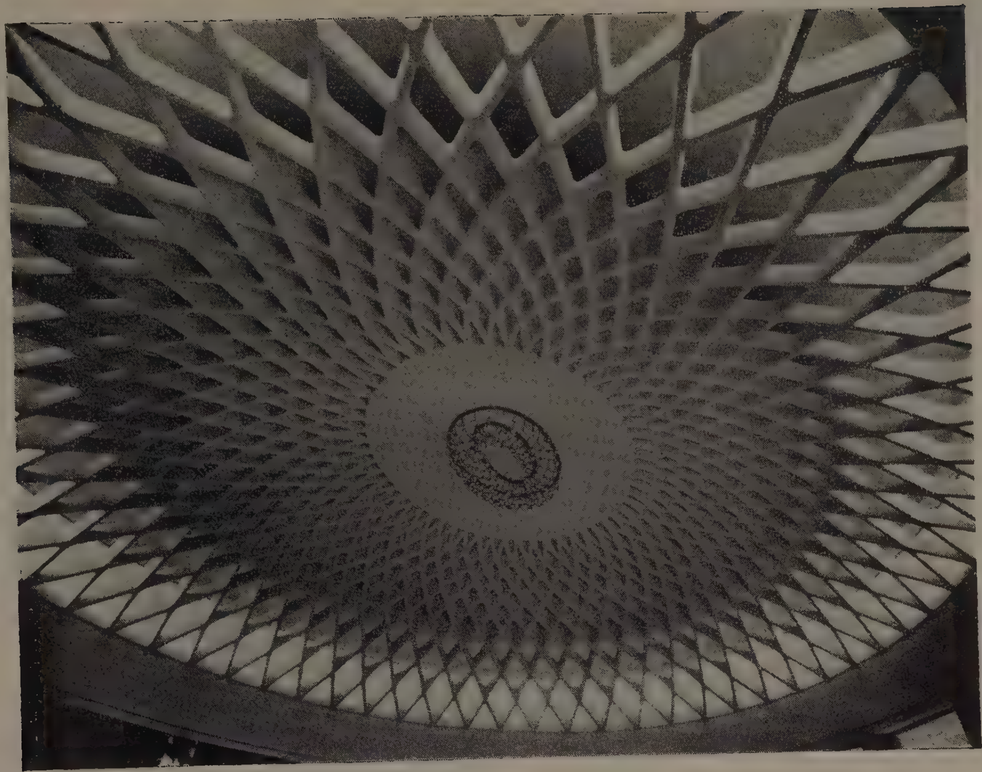


Fig. 19.—Chianciano (1952). Elliptic Vault with Prefabricated Elements

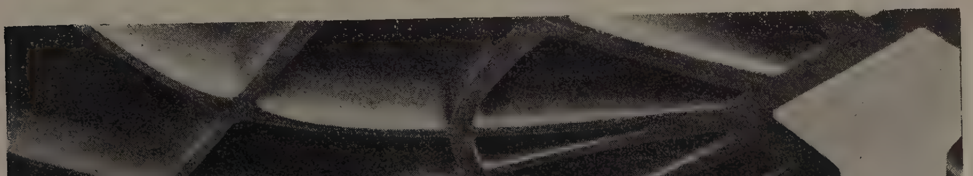


Fig. 20.—Gatti Wool Factory, Rome. Ceiling showing Mushroom-type Columns

characteristic of reinforced concrete. I believe that precasting, the use of " ferro-cement " and methods of roof construction with travelling " ferro-cement " formwork, may be a not unimportant step in this direction.

In closing, I should like to mention the contribution that reinforced concrete has made to the development of present-day tendencies in architecture.

After the first unfortunate attempts to adapt the new

Fig. 21.—Model—UNESCO Building, Paris

Fig. 22.—UNESCO Building, Paris

material to the structural forms of masonry or timber reinforced concrete, spurred on by technical requirements and by its own unlimited possibilities, turned very quickly towards new structural forms, which, to the surprise of their inventors themselves, were found to possess an inherent beauty of their own.

It can be said that the most characteristic architectural forms of reinforced concrete in these last few years have been at once the cause and the consequence of a widespread orientation towards a genuinely constructional architecture, which has very quickly reached every country and every aspect of construction.

Perhaps, because we are taking part in it ourselves, we do not sufficiently realize how profound is the change between the architectural concept of the first part of this century and of the present day, and how important it is to have freed Architecture from a complex of rules and traditions which, however much they

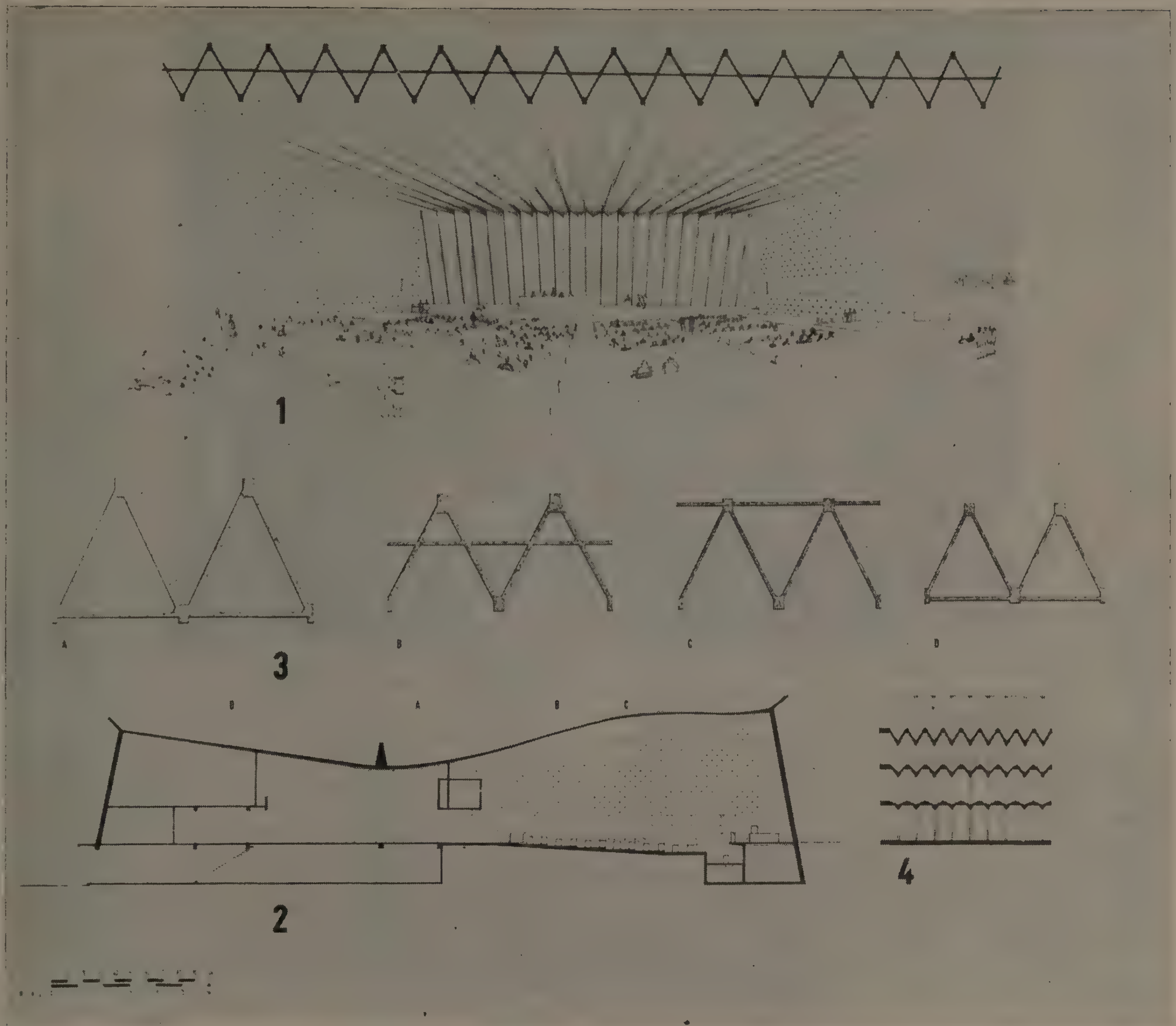


Fig. 23.—UNESCO Building, Paris

corresponded to structural reality at the time of their inception, have gradually lost any significance and become a sterile formalism.

The present moment in architecture is full of promise, but the danger of slipping into structural formalism should never be overlooked : alarming symptoms of it can already be seen in the architectural work illustrated in the periodicals of all countries.

This derives from the fact that too often, through a lack of understanding of its structural and constructional *essence*, a structure is considered solely on the basis of its external appearance—which people try to adapt to a variety of different problems both as regards dimensions and strength.

The result is always unfortunate. I am absolutely certain that the prime condition of architectural expression in a structure is the correctness and, I might say, the inevitability of its structural design.

Constructional complications, or designs that require structural acrobatics, are always a sign of a false structural conception—even to the untrained eye of the non-technical observer.

A consideration of this danger brings us to what, to my mind, is now the most important problem in architecture—the training of the Architect of tomorrow.

To deal worthily with the ever more ambitious architectural projects of the near future the architect must possess—and synthesize in himself—aesthetic sensibility, profound understanding of structural needs, and a precise knowledge of the methods, possibilities and limitations of constructional techniques.

The organization of a course of studies which could in a reasonable number of years provide such a wide and varied training is certainly a very difficult problem. But if we cannot by suitable training succeed in uniting in the young constructor artistic sensibility, technical wisdom and knowledge of building methods, the hopes of the new architecture will be to a great extent frustrated.

Meanwhile, until such time as the training of the *complete architect* can be achieved, good results can be obtained through the sincere collaboration of different people, each contributing the specific knowledge lacked by the others.

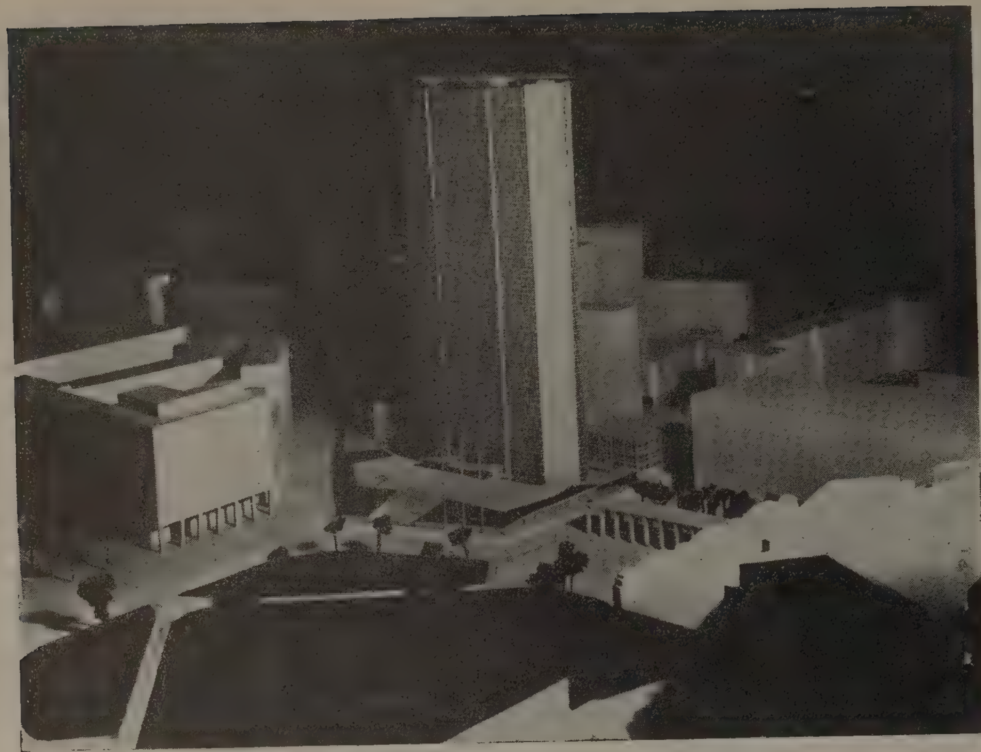


Fig. 24.—Model—Pirelli Office Building, Milan

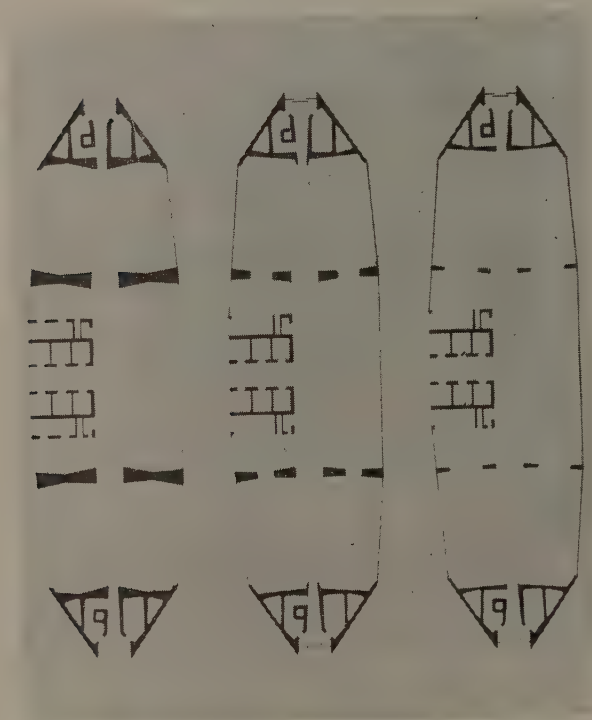


Fig. 25.—Pirelli Office Building, Milan. Plan

Architect, engineer and constructor can, in this way, bring about that union of art and science that is necessary to the solution of any constructional problem.

In the last few years I have had the opportunity of collaborating with architects of great capacities and artistic sensibility, in the conception and development of several outstanding projects, and I must say that this collaboration has been carried out with mutual satisfaction and with results which I consider interesting.

I would mention in this connection the UNESCO building in Paris, in which I collaborated with the architects Breuer and Zehrfuss.

Fig. 26.—Project—Central Station, Naples

I would also like to mention the Pirelli offices in Milan, a notable architectural conception by the architects Ponti, Fornaroli, and Rosselli, studied in collaboration with Prof. Danusso, and engineers Valtolina and Dall'Orto ; the project for the new Central Station at Naples, which was carried out in collaboration with the architect Vaccaro ; and the new Palace of Industry Building in Paris.

I have also observed that the contribution of technical constructional knowledge is only effective if it is brought into collaboration with the architect from the inception of the scheme ; as with living creatures, it is very difficult to eliminate in the development stage any initial deficiency or malformation.

It is clear that the whole field of construction, which stretches from the cultural formation of the architect on the one hand to the industrial organization of construction on the other, is in a state of rapid and progressive development which demands a bringing up to date of both ideas and techniques.

All the efforts of those who have at heart the progress of architecture will still be inadequate to define, to study and to solve so many and such complex problems.

Discussion

The Chairman, after welcoming to the meeting the Italian Ambassador, Count Vittorio Zoppi, proposed a hearty vote of thanks to Professor Nervi for his magnificent paper. He then declared the meeting open for discussion.

Mr. Ove N. Arup, who opened the discussion, thanked Professor Nervi for his most interesting talk and said that most of those present were already familiar with much of his work, at least from illustrations, and that was the same as saying that most of them were his ardent admirers.

Professor Nervi had given not only more information, more details and illustrations about the structures he had made but also an insight into what one might call his professional " credo," the guiding principle governing his work, and his views of architecture, structure and building in general. Those views were not entirely new, but they were held with an enviable conviction that was greatly strengthened by his own achievement and it was good that they had been stated so forcibly.

Mr. Arup confessed that he had not realised before reading the paper that Professor Nervi had been responsible for the execution as well as the design of the structures and that the contracts were obtained in competition. That explained a lot and added greatly to the admiration he felt for Professor Nervi and his work. He had vaguely wondered how, as a designer, Professor Nervi could get the contractors to carry out work of this nature ; how he could be certain that his designs were practical and economical propositions. He knew now. Professor Nervi was absolutely right in saying that the best results are obtained when the designer and the constructor are the same person, or when they at least collaborate intimately, share in the responsibility and experience over a number of years. If new ground had to be opened up, then this close collaboration was absolutely essential. Designing was, after all, indicating a method of building and preferably a practical and economical method. That could not be done without knowledge of building costs and this knowledge was best gained by being a builder. Moreover, only thus was a builder, or rather designer, able to back his own ideas.

Professor Nervi had mentioned that a designing contractor may suggest daring solutions which might have seemed impossible to the professional designer. Mr. Arup agreed, but suggested that it might also be the other way round, that the professional designer may have unorthodox ideas which seemed impossible to the contractor and which he therefore could not get carried out, and this reinforced Professor Nervi's argument that the two ought to be the same person or organization.

But this was not the only condition for a brilliant result. Perhaps in extolling the virtues of design competition—which Mr. Arup preferred to " competition tender "—Professor Nervi was inclined to forget the other one, which was that there should be a Nervi at the head of the combined design and construction team, and that point was the more important one. If Professor Nervi had been an ordinary consulting engineer it might still have been much better to let him do the design rather than rely on a competition between less brilliant designers. At any rate, now that he *had* had the necessary building experience, now that his designs instinctively were conceived with an eye on construc-

tional possibilities, his genius for design could be much better exploited by leaving the construction to others, and this was what was happening. He was, as he ought to be, consulted on many more designs than those which his firm could manage to build.

Mr. Arup submitted, therefore, that the question of whether to have consulting engineers or designing-contractors was not quite as simple as would appear from Professor Nervi's paper. There was on the one side the desirability of the client having an independent adviser, and of a firm of consulting engineers being able to range over a wide field and obtaining more design experience with different materials and methods instead of being dependent on the resource and experience of a single contractor, but there were on the other side the very real advantages mentioned by Professor Nervi, of which a very important one was that one got competition in design and not only in building. This was a factor which acted as a powerful stimulant to good design. That stimulant was sadly missing in this country ; we placed far too little value on good design. In fact, officially there was no such thing as good or bad in this sphere ; there were only designs produced by qualified architects and engineers and unqualified architects and engineers. The former were all supposed to be good and secured the same fee, and they must not be compared or criticized, so once one had committed oneself to the professional designer, one had had it for good or bad. We were scrupulously fair in allotting the contract to the lowest bidder, sometimes at the cost of considerable loss of quality, but we took no trouble, or rather there was no machinery enabling us to obtain quality of design. We had quantity surveyors, but no quality surveyors, and yet to get the best design was so much more important than to obtain the lowest tender for a given design.

Mr. Arup agreed it was not easy to solve this problem and the whole question was far too complicated to deal with at the meeting, and he had in fact no very satisfactory solution to offer—none, at least where the system as such would ensure the right result. It depended so much on the person. He had, for the major part of his working life, been with designing contractors and had therefore had experience of those systems. He confessed he was much happier as a consulting engineer, even if he sorely missed being able to try out new ideas in practice, but this did not mean that he necessarily preferred this system as such. It was only that in this country it was the prevailing system and if one wanted to design one got a better chance as professional designer.

There was so much else in Professor Nervi's paper he would have liked to discuss, but time did not permit and he hoped someone else was going to take up the question of formalism in architecture. He could not entirely subscribe to Professor Nervi's dictum that good architectural form cannot, and must not, be anything but efficient structural form. He agreed that that was ideal, but it depended on the type and scale of building. He was sure that Professor Nervi was himself a formalist in the best sense of the word, and would instinctively reject structural forms which were not at the same time inspiring and harmonious—and economic structure need not be that.

Stating that he would leave this question to others, Mr. Arup concluded by thanking Professor Nervi again for his inspiring message.

Mr. BRYAN WESTWOOD expressed his admiration of Professor Nervi's buildings and particularly the Turin Exhibition Hall. Then turning to more technical things, he said the point which had interested him more than anything else that evening was the wonderful freedom that Professor Nervi had evolved in the handling of concrete by the elimination of the shuttering. He was sure that in the years to come that would be the particular contribution Professor Nervi had made. He had made, as we had seen, an entirely different thing of concrete. One could see the lines of force that one got with iron filings and a magnet suddenly appearing in concrete—an entirely different conception—and he thought it was probably this discovery of Professor Nervi's which had given the intense liveliness that all his buildings had, and had really opened up the way for the full scope that is the maturity of genius.

Mr. Westwood hoped he would not introduce any discordant note in pointing out the danger of accepting too literally the fundamental truths that had been brought out in the paper. As Mr. Arup had already said, we were not all Professor Nervi's and the lesser brethren were hardly likely, necessarily, to be successful by the same methods. Mr. Westwood thought that, carried too far, the engineering economy of which Professor Nervi spoke might eliminate colour, texture and all the tactile qualities of materials which in themselves were not particularly economical or particularly efficient, but which did give some of the outstanding qualities to buildings ; and Professor Nervi was speaking of the real giants—buildings where structure was of the most vital significance, and Mr. Westwood was sure that Mr. Arup was hoping that someone would develop the points about formalism, which applied much more to smaller than, perhaps, more structural buildings. Again, in the search for the utmost economy of structure and efficiency one did not have to think of the building next door, of which the wretched architect had to think only too hard.

Mr. Westwood thought the competition-tender was obviously more than a device just of organisation. The resulting integration of engineer, architect and builder did produce the refinement of quality of structure which we had seen. He had practised architecture for quite a number of years, but he was sure he had got quite a long way further in his own work since he had tried to build his own house, with his own hands.

Continuing, Mr. Westwood suggested that the real difficulty in all our minds was to find people of sufficient calibre to work in the way which we had heard. He felt it must place the most terrifying responsibility on any committee, not only to have to judge which was the lowest tender—which was often a very difficult thing to decide—but also which was the best design and which, of a series of tenders, combined the best of both worlds. He thought that such a difficulty was greatly increased in England by the non-critical client of public opinion.

Mr. F. J. SAMUELY, who was unable to attend the meeting, sent a written contribution, which was read by Mr. Newby, in which he said he had read the lecture with great pleasure and interest. His interest was equal both for the description of the work, and the very concise reference to those problems which comprised the relationship between architect and engineer.

Mr. Samuely had the privilege of seeing some of Professor Nervi's buildings the previous year, but long before that he was an admirer of his work and personality. He shared many of the views expressed by Professor Nervi, and particularly those on architectural education. But there was, none the less, one point

which he wished to take up, namely, the question of the architectural expression of structure.

Professor Nervi had stated very definitely that the outward appearance of a good building could not, and must not, be anything but the visible expression of an efficient structural or constructional reality. Mr. Samuely did not agree, however, that this could be followed to the full, and thought Professor Nervi may have been misled into making such a definite statement by two facts.

The first fact was his own personality : he was so much an architect as well as an engineer that when he designed a structure, his gift for architectural expression was such that it influenced his design to the extent that the ideal combination was a natural outcome, and this one did not expect from the average or, indeed, prominent engineer, who was more concerned with the calculation than with appearance.

The second point was that Professor Nervi had designed mainly large buildings of one cell, and these were the type of buildings for which his statement was possibly correct, more so than buildings of a smaller and more complicated nature. Buildings such as schools, hospitals and factories had many functions, of which the structural stability was only one. The structural system was an entity of its own and was dealt with as such, but the architect had to deal with the building as a whole and often, in fact with the relationship of a group of buildings. In some cases it might be a legitimate act on the part of the architect to suppress the structure completely, rather than to treat it indifferently. On the other hand in an Exhibition Hall or a railway station, the inspiration might spring primarily from the structure, because it incorporated the main functions of the building, and was usually visible. Mr. Samuely felt that Professor Nervi's statement was probably correct for such buildings.

The Turin Exhibition Hall gave Mr. Samuely the most pleasure and was an excellent example of complete unity between structure and architecture. He wondered whether any one of his buildings gave Professor Nervi greater pleasure than the others.

With regard to the question of economy in building, Mr. Samuely felt that this could invariably be achieved if the visible expression and the structure were in harmony. The structure might have to be suited to the visual expression, but this was so much better than cases where space and money were wasted in order to hide the structure. This destroyed the relationship between cause and effect, and was very different from the buildings described by Professor Nervi. Mr. Samuely did not think that economy was necessarily of prime importance, though it had to be practised in most cases. It was invented by man, and was one of the few things that he did not copy from nature. The idea that economy should always be the dictator was misleading, and we often had faith in the functional expression as being most economical. History could teach us to the contrary ; when we looked back on the architecture of the past we could see that in times of rapid progress when available materials were strained to the utmost, functional dominated visible expression as in early Gothic times. It might even be said that the visible expression function of a building was a sign of strain, and the reverse a sign of relaxation.

Mr. Samuely referred briefly to Professor Nervi's suggestions for architectural education. Whilst agreeing with all the sentiments expressed by him, and that it was important for an architect to have adequate training in engineering so that he could understand the engineers' problems, he felt at the same time there were so many difficulties which had to be overcome that it was understandable that there was reluctance to give full training in architecture and engineering to one person. The field was so vast that only a person who was unusually gifted could master both. Much could be achieved, however, if architects, engineers and the leaders of the contracting world could be taught to speak the same language, so that they could understand the elements of each other's activities. We were very far from that in this country, and from his impressions of continental countries, including Italy, it was the same there.

Mr. Samuely also felt it extremely important that all those who were creating the building trade should share their studies for a certain period before branching out as specialists, but this had been said so many times before that it was high time it was put into practice.

Mr. E. D. Mills added his thanks to Professor Nervi for the lecture and the great work he had done in engineering in Italy, and for the inspiration he had given to architects and engineers in other countries.

Just after the war, continued Mr. Mills, someone invented a rather unpleasant phrase in relation to new and rather stodgy buildings erected in this country, and called them " buildings of the new tradition." Buildings so described were on the whole primarily unpleasant and rather dull, and the suggestion was that this type of dreary building was in fact the true follow-up of the traditional building of the past. As an architect, he thought that was largely nonsense, because he believed we had seen the perfect example of true traditional building that evening.

He had often wondered what Gothic builders would do if they were presented with present-day problems and present-day materials and techniques. He felt they would build very much like the buildings we had seen on the screen. Recalling to mind the interior of such buildings as Kings College Chapel, Cambridge, he said there was as incredible family likeness between such a building and much of Professor Nervi's work.

Another great similarity was the method of execution. Gothic builders designed and built experimentally—they often built until the thing fell down because it was too thin, or too daring, and then they constructed it a bit tougher the next time. Professor Nervi designed and built, and in many cases built after experimental work and testing in the laboratory, or testing on the site. Mr. Mills thought it was that approach to building as much as anything else which produced the results we had seen and he hailed Professor Nervi as the New Gothic Architect, and as the true traditionalist.

Finally he asked two questions which he hoped Professor Nervi would be able to answer later on. Firstly, how did he get this sort of finish of reinforced concrete ? Most of our contractors seemed to regard concrete as a rather haphazard mixture of water, cement, sand and pebbles, and generally speaking, much too much water. How did these very fine finishes and very beautiful lines get built into the job ? Mr. Mills supposed the answer to be that Professor Nervi built as well as designed, but he thought there was probably a bit more in it than that. Secondly, he would be interested to know how the dome structures which had been shown were water-proofed. Many of the designers of light domes in this country had had trouble in water proofing their structures, and he would be most interested to hear how Professor Nervi carried that out.

Lastly, Mr. Mills added his plea for the early collaboration of architect, engineer and builder. He said it was not necessarily a fact that all works of builder-designers were the same as Professor Nervi's. One had seen a good deal of building work done by builder-designers, and most of it was pretty frightful. He thought Mr. Arup had made the real point, that, at the head of the organisation one needed a Nervi. He did not think there were enough to go round, but perhaps we could train some to follow. He was, however, keen on the architect, engineer and builder collaboration, and he underlined the point and suggested that not only the architect and engineer were important at the early stage of the job, but the builder as well, so that they could all three come in at the ground floor and start at the same time and all three could work on the problems and produce the solutions that they desired.

He was intrigued by Mr. Arup's idea of quality surveyors. He would like to know where they were going to be trained and who would decide whether they were to be elected as Associates or as Fellows. That was an intriguing idea.

THE CHAIRMAN then invited Professor Nervi to reply through the interpreter to any questions which had been raised.

Dr. P. B. MORICE (for Professor Nervi) said he would like to reply to Mr. Samuely's question " which particular building of those he had designed and constructed had given him the greatest satisfaction ? " Professor Nervi found it difficult to answer since although the solution of each particular problem had given him great pleasure he always felt that he could do better in his next building.

Professor Nervi also wished to make a point about Mr. Samuely's comment on structural functionalsim in architecture. When he said structural functionalism was all important he was directing his remarks towards large structures of the type he had shown that evening and agreed that it was not necessarily important in small jobs.

In concluding the business of the evening, the CHAIRMAN said we had learnt from Professor Nervi that in structures of sufficient size for them to be prominent a true solution of the structural difficulties led to quite exceptional beauty if they were handled by genius such as Professor Nervi's, and he thanked him very much for the way he had presented the paper and answered the few questions which were put to him.

Book Reviews

Residual Stresses in Metals and Metal Construction, edited by W. R. Osgood for Ship Structure Committee under direction of National Research Council. (New York : Reinhold Publishing Corporation, 1954). 9 in. × 6 in. 363—xii pp. 80s. ($10).

The question of whether or not residual stresses affect the strength and behaviour of constructions has been a favourite and hotly disputed topic for discussion amongst engineers and scientists since the advent of welding. There is no doubt that in the early days fears of the possible effects of residual stress have been responsible to a large extent for the diffidence of many engineers to use this new process of fabrication—despite the fact that the presence of similar stresses in castings and in all rolled plates and sections was generally known and disregarded. These fears, however, were allayed to a large extent by the rapid growth of welded construction and the absence of disasters prophesised by the anti-welding fraternity.

The sudden and apparently inexplicable failure of the Hasselt bridge had the effect of heaping coals on a dying fire and the old controversy was revived—only to be stifled by the advent of war and the dire need to increase production of all types of war stores and equipment, a need which could be met only by the general use of welding. Whilst there is no doubt that, with the single exception of Liberty ships, the behaviour of such stores left nothing to be desired—this single exception clearly showed the need for the solution of the problem, and the vast amount of post war research in many countries was the inevitable result. The object of " Residual Stresses in Metals and Metal Construction " is to collate the results of research and experience gained so far, and for this reason this book cannot fail to be of interest to students of the subject.

The work, described in the preface as a Monograph, is a collection of 19 papers by 22 authors from U.S.A. (13), Great Britain (5), Belgium (3), Germany (1), and what might be described as a pronouncement on the subject by the (British) Admiralty Ship Welding Committee. The Authors are all well-known names in their respective countries and many have an international reputation. The subjects range from theoretical studies of the nature and influence of residual stress, its measurement and general reviews of research, to details of tests on actual ships and some machine components—as well as examples of troubles encountered in the fabrication and an indication of how they were overcome. There is also a summary, lists of references and bibliographical sources, and an index.

In general, the accent is on studies and research—which perhaps is not surprising since no less than seventeen of the Authors are drawn from Universities and Research Organisations. For this reason this work is, possibly, more of interest to members of Industrial Research and Development staffs, personnel of Research Organisations, the Technical Teaching Profession and post graduate students. The engineer engaged in the fabrication of welded work will, to a lesser extent, likewise find it of interest—as also will the designers of ships and of the particular machine components and pressure vessels which are the subjects of the tests and examples previously referred to. But the engineers who have been waiting for an answer to the general question and looking for some clear cut rules to be applied in calculations will not find them in this volume ; the Authors appear to be more or less divided on most aspects of the subject and the monograph could be regarded as providing to a greater or lesser extent both confirmation and denial to most schools of thought. In the words of the Cockney " you pays your money and you takes your choice "—and the money you pay is £4 0 0d. in this country or $10 in the U.S.A.

(*continued on page 178*)

Portal Frame Analysis by Moment Area Methods*

Written Discussion on the Paper by Mr. J. F. Horridge

Professor R. G. Robertson (Member) : The Author is to be congratulated on a new principle he has used and which can be stated as follows :

In a frame containing several redundants the analysis may be made in two stages.

In the first stage the analysis is made with only a portion of the redundants present and this analysis gives the " load stresses " to be used in the frame for the second stage.

In the second stage the stresses due to nominal values of the remaining redundants are found while the frame is statically indeterminate in regard to the first redundants.

By this method the number of simultaneous equations to be solved may be reduced to a small proportion of those originally present.

For vertical loads the analogy between a continuous rafter and a continuous beam gave a ready means for evaluating the " load moments " in the frame.

The Author had assumed that the technique of the application of Möhr's equations to his frames was commonly known, but the method given only applied to vertical loads and appeared to be a development for a particular case of a general method† given recently by the writer, which described the techniques (and both of the Author's Conclusions) in detail, and was, at that time, (some six years ago), not generally used, since strain energy and column analogy methods were mostly in vogue ; the above mentioned 1949 Maclachlan lecture may be referred to in regard to the Author's suggestion that his method was entirely original.

The Author also appeared to assume that the application of the well established " moment area " methods to calculations for straight continuous beams would automatically be applied to continuous rafters which are not straight, and which could have supports at widely different levels, and this might well be demonstrated since it limited the loading to vertical loads only and especially as the second part of the calculation does not deal with applied loads, but with initially applied moments.

The advance the Author had made appeared to be the preliminary elimination of the vertical redundants, which depended on and could be evaluated in terms of the horizontal redundants.

This device reduced the $(2n - 1)$ simultaneous equations previously required for n bays, to a separate set of $(n - l)$ simultaneous equations for the vertical redundants in terms of the n horizontal redundants and a separate set of n simultaneous equations for the n horizontal redundants.

A minor criticism of the diagrams in the Author's Tables I and II was that the type of moment intended by the Author's arrows was not at all clear since the arrows in Table (2) appeared to mean a " hogging " moment, causing tensile stress in the upper fibre, whereas the reverse was found to be intended by independent calculation.

As it was not possible to observe the nature of the moments from the calculations given, this might have been made more explicit, and the same directions used for these arrows in Tables I and II.

The method could equally well be applied to similar frames with fixed feet by developing " moment distribution " methods for finding the redundant continuity moments with the feet free to move laterally but not to turn, but the use of " moment area " methods gave twice as many equations as there were bays in this case which appeared to make " moment area " methods unwieldy for several bays with fixed feet.

However for the case of pinned feet, and vertical loading, the Author's tables should prove extremely useful.

Mr. A. V. Bowen and Mr. P. G. Ridley : We were particularly interested in Mr. Horridge's article, as we have been using this method for several years, following Mr. Robertson's Maclachlan prize-winning lecture on the same subject (The Structural Engineer, Nov. 1949). Mr. Horridge's approach differs somewhat from Mr. Robertson's but broadly speaking, the methods are the same. However, we are greatly indebted to Mr. Horridge for the neat extension he has devised to cover the redundancies of multi-span portals. Any method which results in a reduction of the number of simultaneous equations to be solved is a boon to the designer.

We have in the past designed many latticed portal frames up to 220 ft. span in aluminium alloy, and for these we have used Mr. Robertson's method to obtain approximate values of H for vertical loads, roof suction, and side wind. For this purpose, centre-line dimensions have been used, a constant inertia assumed, and allowance made for the eccentricity of the vertical reaction from the centre-line of the leg. The sections required for the frame have then been found by normal graphical and tabular methods, and the assumed values of H checked by strain energy as follows :—

* Published in *The Structural Engineer*, Vol. XXXII, No. 8, pp. 215-222. (Aug. 1954).

† See Maclachlan Lecture, *Structural Engineer*, November 1949. R. G. Robertson.

$$\text{Error} = -\frac{\Sigma \cdot \dfrac{FkL}{AE}}{\Sigma \cdot \dfrac{k^2L}{AE}}$$

where $F =$ force in any member due to applied loading including assumed value of H

$k =$ force in member due to unit horizontal force at pins acting outwards.

The error in H has been found to be less than 4 per cent in all cases and has been ignored except in the construction of Williot-Möhr deflection diagrams.

We feel that a different theoretical approach from that given would help the designer to appreciate both the limitations and possible further applications of the method. Mr. Horridge approached the problem from Möhr's theorem, whereas Mr. Robertson worked from the fundamental equation for beam curvature. We prefer to work from Castigliano's theorem. Considering strain energy due to bending only this can be expressed in the form :

$$\text{Deflection } \Delta = \int \frac{Mm \,.\, ds}{EI}$$

where $M =$ moment due to the applied loading

$m =$ moment due to a unit load applied at the position and in the direction of the required deflection.

For a single-bay 2-hinged portal with inward horizontal reaction H, outward deflection at feet

$$\Delta = \int \frac{Mm \,.\, ds}{EI} + \int \frac{-(Hm)m \,.\, ds}{EI} = 0$$

$$\therefore H = \frac{\displaystyle\int \frac{Mm \,.\, ds}{EI}}{\displaystyle\int \frac{m^2 \,.\, ds}{EI}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $M =$ moment under simply supported conditions

$m =$ moment due to unit load acting outwards at pins

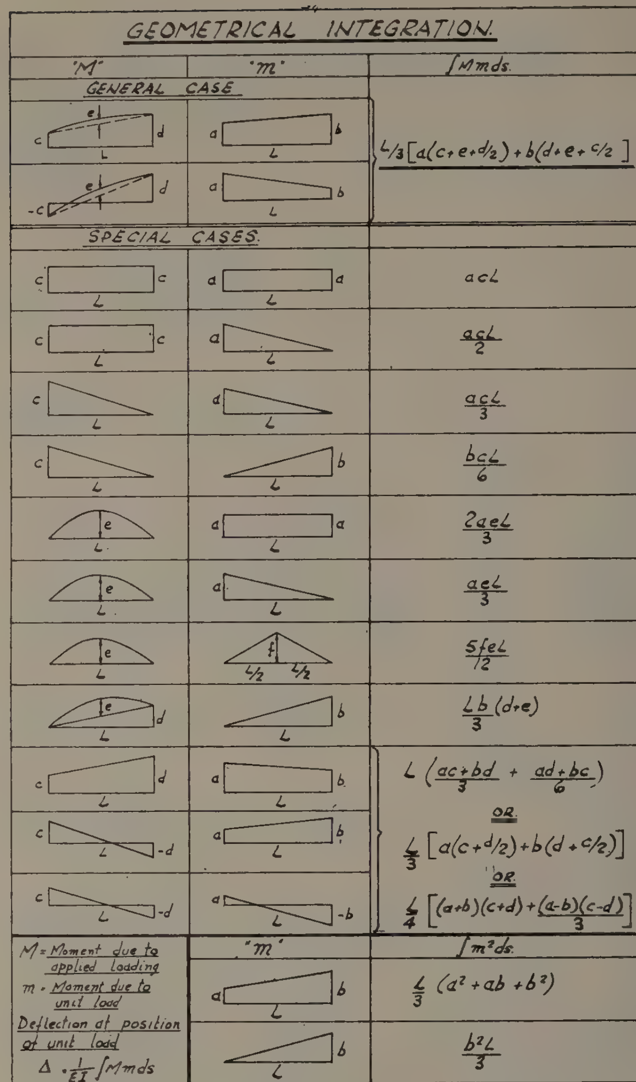
But $m = y =$ vertical height above base-pins.

$$\therefore H = \frac{\displaystyle\int My \,.\, ds}{my \,.\, ds} \quad \text{(assuming constant } E \text{ and } I\text{)}$$

$$= \frac{\text{1st moment of area of } M \text{ diagram about pins}}{\text{1st moment of area of } m \text{ diagram about pins}}$$

$$= \frac{\Sigma A\bar{y} \text{ for } M \text{ diagram}}{\Sigma A\bar{y} \text{ for } m \text{ diagram}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

There are, however, many types of structure where m is not equal to y or x throughout the frame. Among these are multi bay portals and knee-braced portals. For knee-braced portals, however, the area moment method gives a sufficiently accurate value of H (within about 3 per cent.). In other cases this is not so, and it is then necessary to use equations (1). To avoid tedious mathematics, we have produced the accompanying table to give a simple arithmetical solution. It has been found useful also in calculating deflections in continuous beams, portal frames and multi-storey rigid frames.

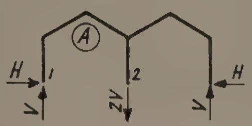


Mr. G. Mundy (Associate-Member) : In his paper on the analysis of multi-bay single-storey frames with pinned feet Mr. Horridge seeks to reduce the labour of solution by using Professor R. G. Robertson's method of semi-graphical integration[1] supplemented by tables of reactions, moments, and horizontal displacements of the pins. By equating the horizontal displacements of the pins due to the applied load (with horizontal constraints removed) to those caused by the H forces, he reduces the number of simultaneous equations to one equation per bay, and semi-graphical integration is probably one of the simplest and most straightforward methods of obtaining the required equations.

The Author restricts his scope considerably, however, in attempting to reduce the work still further by the use of tables which apply only to frames of two shapes, i.e. pitched and flat-topped, and to frames with all bays identical. All that is required for the solution of this particular type of frame is a table of formulae from which the horizontal and vertical reactions can be calculated by simple arithmetic without having to solve any simultaneous equations at all.

TABLE 1 — REACTIONS DUE TO SYMMETRICAL LOADING

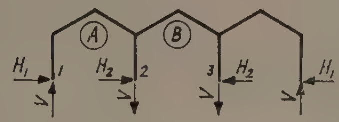
ALL FEET PINNED : ALL BAYS IDENTICAL : INERTIA OF RAFTERS = I_1 : INERTIA OF LEGS = I_2



$$H = \frac{A - \frac{3j}{2L}\cdot A_1}{\frac{s}{I_1}\left(\frac{j^2}{2} + \frac{p^2}{6}\right) + \frac{h^3}{3I_2}}$$

$$V = \frac{3}{2L}\left(jH - \frac{I_1 A_1}{sL}\right)$$

FOR NOTES ON USE OF FORMULAE SEE TABLE 2



$$H_1 = \frac{mc + nb}{ac - 2b^2}$$

$$H_2 = \frac{m(2b-c) + n(a-b)}{ac - 2b^2}$$

$$V = \frac{3}{5L}\left\{j(2H_1 + H_2) - \frac{I_1}{sL}(A_1 + B_3)\right\}$$

IN THE ABOVE FORMULAE :

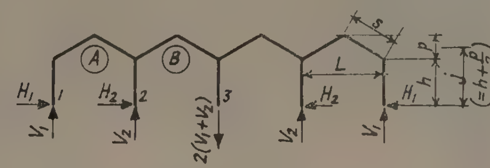
$$m = A - \frac{3j}{5L}(A_1 + B_3)$$

$$n = B - \frac{6j}{5L}(A_1 + B_3)$$

$$a = \frac{s}{I_1}\left(\frac{7j^2}{5} + \frac{p^2}{6}\right) + \frac{2h^3}{3I_2}$$

$$b = \frac{3sj^2}{5I_1} + \frac{h^3}{3I_2}$$

$$c = \frac{s}{I_1}\left(\frac{4j^2}{5} + \frac{p^2}{6}\right) + \frac{2h^3}{3I_2}$$



$$H_1 = \frac{mc + nb}{ac - b^2}$$

$$H_2 = \frac{m(b-c) + n(a-b)}{ac - b^2}$$

$$V_1 = \frac{3}{7L}\left\{j(3H_1 + H_2) - \frac{I_1}{sL}(2A_1 + 2B_3 - B_2)\right\}$$

$$V_2 = \frac{3}{7L}\left\{j(H_2 - 4H_1) + \frac{I_1}{sL}(5A_1 + 5B_3 - 6B_2)\right\}$$

IN THE ABOVE FORMULAE :

$$m = A - \frac{3j}{7L}(2A_1 + 2B_3 - B_2)$$

$$n = B - \frac{3j}{7L}(A_1 + B_3 + 3B_2)$$

$$a = \frac{s}{I_1}\left(\frac{8j^2}{7} + \frac{p^2}{6}\right) + \frac{2h^3}{3I_2}$$

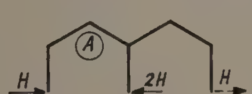
$$b = \frac{3sj^2}{7I_1} + \frac{h^3}{3I_2}$$

$$c = \frac{s}{I_1}\left(\frac{2j^2}{7} + \frac{p^2}{6}\right) + \frac{h^3}{3I_2}$$

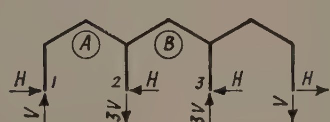
Table 1

TABLE 2 — REACTIONS DUE TO SKEW-SYMMETRICAL LOADING

ALL FEET PINNED : ALL BAYS IDENTICAL : INERTIA OF RAFTERS = I_1 : INERTIA OF LEGS = I_2

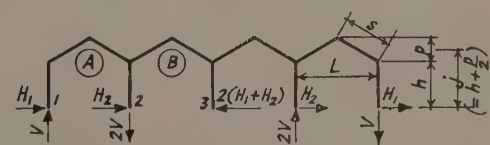


$$H = \frac{A}{\frac{s}{I_1}\left(2j^2 + \frac{p^2}{6}\right) + \frac{h^3}{I_2}}$$



$$H = \frac{A - \frac{j}{L}(A_1 + B_3)}{\frac{s}{I_1}\left(j^2 + \frac{p^2}{6}\right) + \frac{2h^3}{3I_2}}$$

$$V = \frac{j}{L}\cdot H - \frac{I_1}{sL^2}(A_1 + B_3)$$



$$H_1 = \frac{mc + nb}{ac - b^2}$$

$$H_2 = \frac{m(b-c) + n(a-b)}{ac - b^2}$$

$$V = \frac{3}{4L}\left\{j(2H_1 + H_2) - \frac{I_1}{sL}(A_1 + B_3)\right\}$$

IN THE ABOVE FORMULAE :

$$m = A - \frac{3j}{4L}(A_1 + B_3)$$

$$n = B - \frac{3j}{4L}(A_1 + B_3)$$

$$a = \frac{s}{I_1}\left(\frac{5j^2}{4} + \frac{p^2}{6}\right) + \frac{2h^3}{3I_2}$$

$$b = \frac{3sj^2}{4I_1} + \frac{h^3}{3I_2}$$

$$c = \frac{s}{I_1}\left(\frac{5j^2}{4} + \frac{p^2}{6}\right) + \frac{h^3}{I_2}$$

NOTES ON THE USE OF THE FORMULAE

1. SYMBOLS :

A	= BAY (A)	AREA MOMENT ABOUT HORIZONTAL LINE THROUGH PINS
B	= BAY (B)	" " " " " " "
A_1	= BAY (A)	" " " VERTICAL LINE THROUGH PIN 1
B_2	= BAY (B)	" " " " " " " 2
B_3	= BAY (B)	" " " " " " " 3

2. AREA MOMENTS REFERRED TO ARE THE MOMENTS OF AREA OF THE 'FREE' M/I DIAGRAMS DUE TO THE APPLIED LOADING, AND ARE CALCULATED AS IN ROBERTSON'S METHOD OF SEMI-GRAPHICAL INTEGRATION. 'FREE' M/I DIAGRAMS ARE DRAWN ON THE TENSION SIDE OF THE MEMBER AND AREAS INSIDE THE BAY ARE RECKONED POSITIVE.
3. 'FREE' REACTIONS MUST BE ADDED ALGEBRAICALLY TO THOSE SHOWN.

Table 2

The writer has derived equations for the reactions, using methods similar to those employed in the paper, and these are set out in the appended Tables 1 and 2. Table 1 gives the horizontal and vertical reactions for symmetrically loaded frames. If the loading is unsymmetrical it must be split into symmetrical and skew-symmetrical loading systems, and the reactions for the latter case can be found by using Table 2. Thus, the tables can be used for any arrangement of loads.

The effect of alternative loading arrangements on any given frame is easily found because the constant terms have only to be calculated once. The tables may be used for flat-topped frames by putting $j = h$, $p = 0$ and $s = L/2$.

The writer has worked out Mr. Horridge's Example 4, using the tables, and the reactions obtained agree closely with the author's values with the exception of the horizontal reaction at the centre pin (.063 ton instead of .28 ton).

References :

1. Semi-graphical Integration Applied to the Analysis of Rigid Frames. R. G. Robertson. *Structural Engineer*, Vol. XXVII, No. 11. November 1949.
2. The Analysis of Engineering Structures. Pippard & Baker. pp. 117.

Dr. P. M. Tezner (Member) : Interrupting the string of basic research articles, the paper of Mr. J. F. Horridge will appeal to the humbler student, working on routine tasks. It rightly claims to be "neat and easy to understand." If the Author considers it to be an "entirely original method" we should say that the method is O. Möhr's, but we accept it as a new proceeding, which eases the monotony of a single track—be it even that of the method of distribution, which answers more questions, e.g. Fixed bases, "I" variable within a span, sidesway, etc.

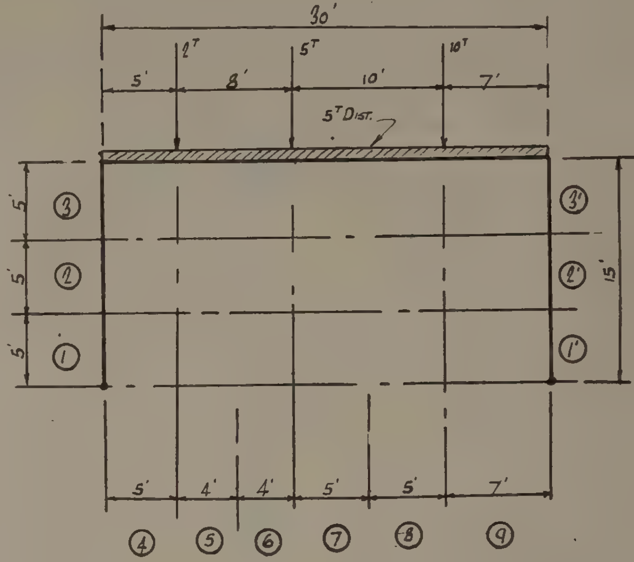
Even then the Author's separation of H forces and exterior loads to be superimposed later was already practised in a period when more arches than portals were designed. Thus the real novelty would be the use of arithmetics, certainly an educational blessing with a public refraining from the shorter ways of algebra. But will such followers relish the solution of four equations of Example 4 ? For a ready reckoner Mr. Horridge's Tables have to compete with Prof. Kleinlogel's comprehensive data book, now available in the English language.

Mr. E. J. Buckley (Member) : I should like to comment on the first section of Mr. Horridge's paper, i.e., on the resolution of the bending moments in single bay portals.

The Hardy Cross Moment Distribution analysis is, of course, normally used for the evaluation of bending moments but in cases of non-rectangular frames or of asymmetrically loaded rectangular frames the method suggested in the paper can, at least in certain instances, be used with advantage particularly in view of the "sway" calculations necessarily involved in the moment distribution method.

However, a tabular computational procedure giving a semi-automatic method of calculation is much to be preferred to that indicated in the paper ; for all but the simplest forms of loading, such as used to illustrate the paper, the method used is unduly cumbersome and also very susceptible to arithmetical and other errors.

A simple tabular method which can be recommended is as follows :—



SECTION	M_o	y	y^2	ds	$M_o y ds$	$y^2 ds$
1	0	2.5	6	5	0	30
2	0	7.5	56	5	0	280
3	0	12.5	156	5	0	780
1'	0	2.5	6	5	0	30
2'	0	7.5	56	5	0	280
3'	0	12.5	156	5	0	780
4	23	15	225	5	1725	1125
5	59	15	225	4	3540	1000
6	80	15	225	4	4800	1000
7	91	15	225	5	6825	1125
8	87	15	225	5	6525	1125
9	44	15	225	7	4620	1575
				Σ	28035	9130

$$H = \frac{28035}{9130} = 3.1^T$$

From basic strain energy considerations it can be shown that :

$$H = \frac{\Sigma\, Mo\, y\, d\, s}{\Sigma\, y^2\, d\, s}$$

(where H, Mo, y and ds have the usual significance) and is identical with the "moment area" concept in the paper.

Graphically or otherwise (a graphical procedure is normally of sufficient accuracy and simplest for complex loading) the "free" B.M. diagram is divided into suitable small sections and the corresponding values of mean BM (Mo) y, y^2 and ds for the particular

section obtained and inserted in the following Table.

(1) Section	(2) Mo	(3) y	(4) y^2	(5) ds	(6) $Moyds$	(7) y^2ds

Columns (6) and (7) are then totalled from which

$$H = \frac{\text{Col. 6}}{\text{Col. 7}}$$

An example is appended of an asymmetrically loaded rectangular frame which clearly indicates the method. The figures given were obtained from quite rough graphical methods which gives a quite sufficient degree of accuracy. The resulting value of H checks almost exactly with that obtained from a normal moment distribution calculation.

Reply by Mr. J. F. HORRIDGE :

It is rather unfortunate that, being absolutely unaware of Prof. Robertson's semi-graphical integration, the writer should cover some of the same ground five years later, and the suggestion of being entirely original is incorrect.

However, it is fortunate in one respect, in that a different approach was taken which greatly reduced the amount of work in multi-span frames. As Prof. Robertson points out, by pre-analysis of the continuity moments over the column, the number of simultaneous equations are reduced from ($2n$—1) to (n—1). In the 4-bay example, this reduced the number of simultaneous equations from 9 to 4 which is considerable.

Several members have corresponded privately with the writer regarding the derivation of the continuity moments over the columns due to H forces and it is hoped the following notes and sketches will clarify the matter.

Fig. A shows a typical free B.M. diagram due to H forces for a 2-bay portal. The deck being free to rotate over the column will deflect somewhat as shown in Fig. B. Slope θ $B.A.$ equals deflection at A divided by L, and $\theta\ B.A. + \theta\ B.C. = 0$. Therefore taking moments of area about A and C respectively (Fig. C) :—

$$\theta\ B.A. + \theta\ B.C. =$$

$$\left(hH, \times L \times \frac{L}{2} - M \times \frac{L}{2} \times \frac{2L}{3}\right) \times \frac{I}{L}$$

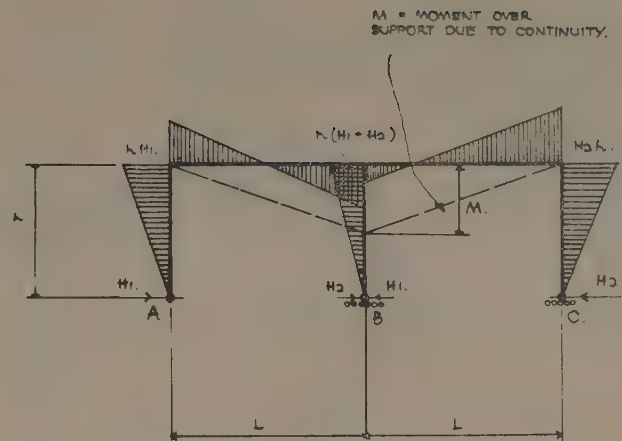
$$+ \left(hH_2 \times L \times \frac{L}{2} - M \times \frac{L}{2} \times \frac{2L}{3}\right) - \frac{I}{L} = 0$$

$$\therefore M = \frac{3h}{4}(H_1 + H_2)$$

This method can be extended to any number of similar bays by equating " double bays " separately ; for example, a 5-bay portal will have four " double bay " equations (viz. : bays 1 & 2, 2 & 3, 3 & 4 and 4 & 5) and four redundant continuity moments.

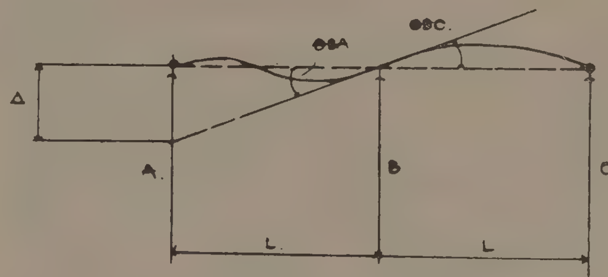
Continuity moments for pitched bay portals are similar to flat frames but using the constant $\left(h + \frac{P}{2}\right)$ in place of h. It is hoped Fig. D is self-explanatory on this point.

The writer regrets that he cannot fully understand Prof. Robertson's statement regarding the treatment of continuous bent rafters being limited to vertical



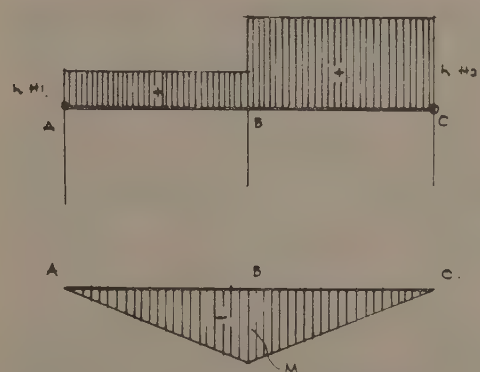
H MOMENT DIAGRAM

Fig. A



DEFLECTED FORM OF DECK BEAM

Fig. B



H MOMENT DIAGRAMS FOR DECK BEAM SEPARATED FOR CLARITY

Fig. C

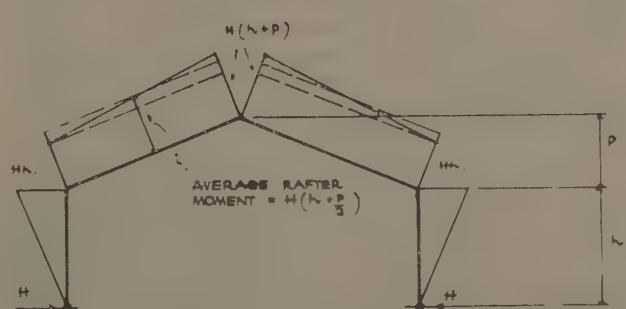
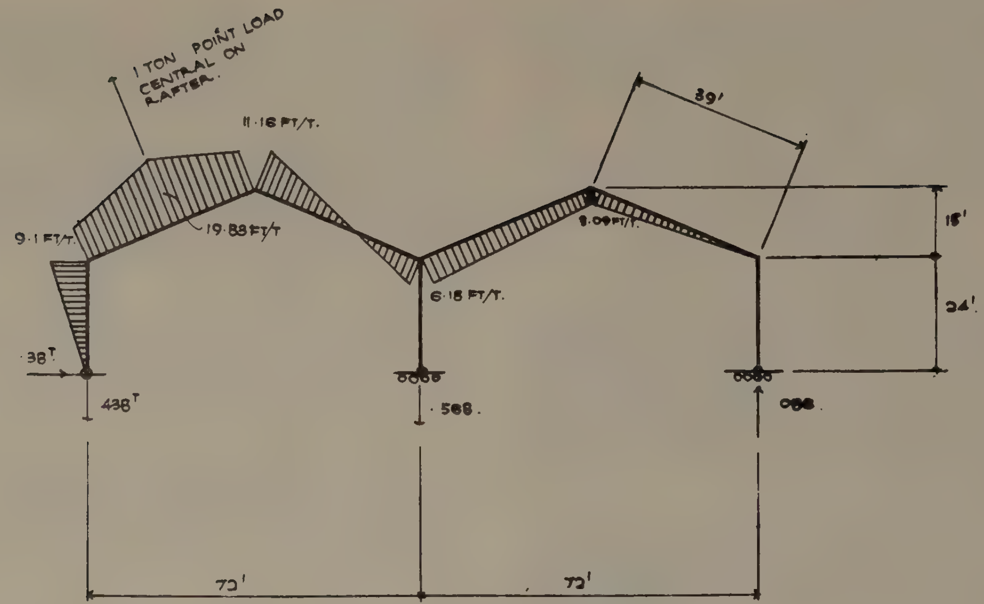


Fig. D



FINAL FREE B.M. DIAG.

Fig. E

loads only. Fig. E shows a final free B.M. diagram for a typical wind suction load on a 2-bay portal. This is actually a combination of three B.M. diagrams. (1) Free for L.H. bay only. (2) Continuity due to vertical forces. (3) Continuity due to horizontal forces.

This final free B.M. diagram has been produced entirely from "Moment Area" theorems. Is Prof. Robertson agreeing that this is correct or not?

The writer wishes to thank the members for their criticisms and general interest taken in the paper, and also the many members who have written privately on the subject.

Book Reviews

(continued from page 172)

Lecture Notes on Plastic Design in Structural Steel, by Lynn S. Beedle, Bruno Thurlimann and Robert L. Ketter. (Lehigh University, Pennsylvania, U.S.A.) 70 pages, 8½ in. × 11 in. Unpriced.

Although Clause 29 of B.S.449:1948 permits the use of the plastic design of structural steelwork, it is only recently that a similar clause has been drafted by the appropriate Committee in the U.S.A. Nevertheless, a keen interest is being displayed in the full-scale research work undertaken at Lehigh and other Universities, with the result that 300 delegates attended the week's Summer Course on Plastic Design in Structural Steel which was held at Lehigh in September, 1955. The course was organised in such a way that there were lectures in the mornings and tests on members or frames in the afternoons, thereby combining theory and practice.

The printed Lecture Notes contain the following chapters: Fundamental Concept, Flexure of Beams, Upper and Lower Bound Theorems, Equilibrium and Mechanical Methods of Analysis, Calculation of Deflections, Modifications to Simple Plastic Theory, Design of Connections, The Problem of Structural Safety Rules of Design and Analysis and Design Examples, together with a comprehensive bibliography.

The work undertaken at Lehigh is complementary to that being done at Cambridge by Professor J. F. Baker and his team and the lecture notes reflect this alliance of thought.

While the whole of the notes are packed with interesting material, the British reader will probably devote most attention to the chapters relating to structural safety, connections and the practical examples.

It can be said that this is the most complete single work which has yet been published on the subject of plastic design and, as such, it can be recommended to our readers.

G.B.G.

Analysis of Statically Indeterminate Structures, by John I. Parcel and Robert B. B. Moorman. (New York: John Wiley; London: Chapman & Hall, 1955). 571 pages, 9¼ in. × 6 in. Price 76s.

The first two chapters deal with deflection of beams and frameworks by most of the standard methods. The next six chapters give methods of solution of statically indeterminate structures with a liberal selection of worked examples. Rigid frames are included with both straight and curved members. Continuous beams and continuous rigid frames are considered with sections varying in the length of a span.

A method of particular interest is one which solves rigid frames with sidesway by the method of moment distribution in one operation only.

The final chapter on suspension bridges contains a much fuller treatment than usual for a book not specially devoted to this type of structure.

This volume can be recommended both as a text book and as a reference book. Some of the symbols used are ones not normally used in this country and a complete list of symbols would have been a help. Advanced students will welcome this book, but they will soon realise that it is not a "first" book on the subject. A good knowledge of Theory of Structures has been assumed by the authors.

F.E.

Institution Notices and Proceedings

ORDINARY GENERAL MEETING

An Ordinary General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 22nd March, 1956, at 5.55 p.m. Mr. Stanley Vaughan, B.Sc., M.I.C.E., M.I.Struct.E., A.C.G.I., M.Soc.C.E.(France), (President) in the Chair.

The following members were elected in accordance with the Bye-Laws. Will members kindly note that the elections, as tabulated below, should be referred to when consulting the Year Book for evidence of membership.

Students

Bishop, John Leighton, of Birmingham.
Blissett, Bernard Clive, of Belper, Derbyshire.
Chik Yu Hung John, of Hong Kong.
Feely, Brian, of Liverpool.
Hawkes, Cyril Dickson, of London.
Jones, Peter Arthur, of London.
Mackie, Stephen George, of Johannesburg, South Africa.
Nassim, Victor Haskell, of Woodford Green, Essex.
Nicholas, Llewellyn Sidney, of Bryncethin, Nr. Bridgend, Glam.
Nursey, John Richard, of Beccles, Suffolk.
Pathanjali, Deivasenapathi, of Madras, India.
Rice, Christopher John, of Staines, Middlesex.
Robson, Michael John, of London.
Smith, David Harry, of Shenfield, Nr. Brentwood, Essex.
White, Michael Percy, of Sheffield.
Wright, Roland, of Deepcar, Nr. Sheffield.

Graduates

Dhillon, Gurbir Singh, B.Sc.(Civil) Punjab, of Sheffield.
Ghatak, Kironmoy, B.E. Calcutta, of Calcutta, India.
Hakim, Ashraf, of London.
Harding, John James, of Kingsway, Derby.
Hart, Charles Patrick, of London.
Haws, Edward Thomas, M.A.Cantab., A.M.I.C.E., of Mangakino, New Zealand.
Hipkiss, Peter, of Darlington, Co. Durham.
Madhav, Chandumal Bachumal, B.E.(Civil) Poona, of New Delhi, India.
Payne, Brian, of Tividale, Nr. Dudley, Worcs.
Peddie, David, B.Sc.(Civil) Glasgow, of Glasgow.
Pegg, Alan Hope, of Stafford.
Ramesh, Coorg Krishniengar, B.Sc., B.E. Mysore, of Roorkee, U.P., India.
Yates, Peter Ronald, of Great Barrow, Nr. Chester.

Member

Tahany, Martin Clifford Augustus, of Leicester.

Transfers

Students to Graduates

Andrews, Robert Alexander, B.Sc.(Eng.) Rand, of Johannesburg, South Africa.
Dawson, James Alfred Jack, of Erith, Kent.
Dickens, William Joseph, of Hednesford, Staffs.
Metcalf, Leslie, of Preston, Lancs.
Porter, John Ellis, of Peterborough, Northants.
Sherbourne, Archibald Norbert, B.Sc.(Eng.) London, of Bethlehem, Penn., U.S.A.
Wellings, Paul Eustace, of Bishops Stortford, Herts.

Graduate to Associate-Member

Wojciechowski, Jan, of East Orange, New Jersey, U.S.A.

Associate-Members to Members

Eddison, James Andrew, M.A.(Cantab.), A.M.I.C.E., of Edinburgh.
Parker, Patrick Ivor, B.Sc.(Eng.), A.M.I.C.E., of London.
Smith, Clifford, of Rickmansworth, Herts.
Smith, William Shearer, A.M.I.C.E., of Lenzie, Dunbartonshire.
Wolley, Alfred Leonard, of London.
Wright, William Cecil, A.I.Mech.E., of Wembley Park, Middlesex.
Wong Gai Hong, of Singapore.

Associate-Member to Retired Associate-Member

Tabrum, Ernest James, of Kingston-on-Thames.

Member to Retired Member

Gibson, Lt.-Col. Charles Herbert, D.L., of Croydon, Surrey.

OBITUARY

The Council regret to announce the deaths of Arthur Fitzsimmons, Peter Clark Hogarth (Members), Alan Trevor Pocock (Associate-Member), Alfred George Maddock (Associate).

RESIGNATION

Notification was given that the Council had accepted with regret the resignation of John Wright (Member).

EXAMINATION RESULTS, JANUARY, 1956

Home Centres

The examinations were held at the usual centres in Great Britain in January, 1956. Thirty-seven candidates entered for the Graduateship Examination, and 345 entered for the Associate-Membership Examination, making a total of 382. Of these, twenty candidates passed the Graduateship Examination and 109 candidates passed the Associate-Membership Examination. The names of the successful candidates are :

Graduateship Examination

Home Centres

Akande, Morakinyo Ayoola.
Bryce, Ian.
Buckton, Geoffrey.
Chate, Hugh Joseph.
Coopland, Jack.
Henderson, Keith.
Hilton, George Geoffrey.
Houston, Robert Stewart.
Hussain, Syed Rafat.
Kwasny, Zdzislaw Wieslaw Roman.
Looby, Kevin Joseph.
Malcolm, William Johnston.

MILLAR, James Graham.
MYERSCOUGH, Francis.
PATEL, Dinker Gordhanbhai.
ROBSON, Keith.
SETTLE, Brian.
SHANMUKHANANDAM, Thiagarasa.
SWALE, John.
WATLING, Terence Roy.

ASSOCIATE-MEMBERSHIP EXAMINATION

ALLEN, David.
ANDERSON, Alexander David.
ANDREW, Alec Albert.
ANDREWS, Harold John.
ASHMAN, Leslie Edgar.
ATTWOOD, John Harry.
AYRES, Donald Claude.
BACON, William.
BANERJEE, Sukumar.
BARNES, Peter John.
BASON, John Roland Thomas.
BERRY, Leonard James.
BLACK, William Angus.
BLACKLEDGE, George Fort.
BOOTH, Richard.
BROUGHTON, Kenneth Henry.
BROWN, James.
BROWN, Walter.
BRYAN, Eric Reginald.
BUCHNER, Trevor Ernest.
BURKE, James Michael.
BURTENSHAW, Raymond Vincent.
CHILTON, William Herbert.
CHIN, Timothy Kwet-Fah
CHRISP, John.
COLLINGWOOD, Geoffrey Frank.
CORBETT, Joseph Frank.
COXHEAD, Peter Leonard.
CRISP, Henry George.
DATTA, Santosh Kumar.
DAY, Alistair Scott.
DESHPANDE, Vasant Balkrishnan.
DOORLY, Dermot Kieran.
EACHUS, Sydney.
FERSZTAND, Jakob.
FISHER, Bob Herbert.
FORD, Keith Alan.
FOX, Ronald Theodore.
FULWOOD, Alan Frederick.
GEDGE, David Gregory.
GHOSH, Asoke Kumar.
HALE, Kenneth Reece.
HALL, Edward Tuffnell.
HARVEY, Michael James.
HAUPT, Arthur Leonard.
HEALD, Raymond.
HEATON, Ronald Allen.
HEATON, William.
HEIGHWAY, Sidney Stephen.
HICKS, Arthur Blamey.
HOLLINGUM, Kenneth.
HOLMAN, Ernest.
HOLMES, Geoffrey.
HOLMES, Gordon Victor.
HUDSON, Benjamin Marshall.
JAFFE, John Walter Paul.
KALNINS, Janis Osvalds.
KARNICK, Pandharinath Dwarkanath.
KERSHAW, Walter Donald.
KLEYNHANS, Evert.
KNOTT, Leonard Richard.
KRAWCZYK, Eugeniusz.
LATHAM, Joseph Royston.
LAWRENCE, David Edward.
LEACH, Peter Edgar.
LEVI, Albert.
LOWSON, William Wallace.
MARKS, Robert William.
MARTINEZ, Philip Anthony.
MILGATE, Peter.
MOORE, Arthur William.
MOORE, John Denis.
MORICE, Peter Beaumont.
NORREY, Albert Brian.
NOSK, Antoni.
OGILVIE, Gavin.
PARISH, Ancel.
PAUL, Francis Colvin.
PENDAL, Bryan Janes.
PIGOTT, Edward Daniels.
PITCHFORD, Brian Edward.
REEVES, Neil.
REFFITT, Michael John Joseph.
RENDALL, William Cutt.
RICHARDS, Gwillim Thomas.
RIMMER, Harold Edwin.
RITCHIE, Alistair George Baldwin.
SCOTHERN, Lancelot Clifford.
SEVILLE, Stanley.
SHEPHERD, John Donald.
SIENKO, Czeslaw Zbyslaw.
SIM, Peter James.
SLADE, Alan John.
SMITH, Graham Trevor.
SMITH, Stanley.
STACEY, Donald William.
STEELE, John James.
STEWART, John.
SUTHERLAND, Ian Murrary.
SZYMANSKI, Witold Janusz.
TAIWO, Emanuel Olatunje.
THOMPSON, Leonard Charles.
TIETZ, Stefan Berthold.
TREVENA, George Frederick.
WARREN, Stanley Edwin.
WESTON, Raymond John William.
WILES, Edward.
WILKINS, Raymond Henry.
WILLIAMS, Frederick Leonard.

EXAMINATIONS, JANUARY, 1956

OVERSEAS CENTRES

The examinations were held in January, 1956, overseas at the following centres :

Aligarh (Delhi), Atbara, Bombay, Brisbane, Bulawayo, Calcutta, Cambridge (U.S.A.), Cape Town, Cooma, Cyprus, Durban, East London, Hong Kong, Johannesburg, Kampala, Karachi, Kingston (Jamaica), Kuala Lumpur, Lagos, Lahore, Lusaka, Madras, Melbourne, Nairobi, New York, Port Elizabeth, Port Moresby, Qatar (Persian Gulf), Salisbury (Southern Rhodesia), Singapore, Tel Aviv, Toronto, Wellington.

Thirty-eight candidates took the Graduateship Examination, and ninety-two took the Associate-Membership Examination, making a total of one hundred and thirty. Of these, seventeen passed the Graduateship Examination and twenty-four passed the Associate-Membership Examination. The names of the successful candidates are :

Graduateship Examination

Brown, Donald Robert.
Cheong Yi Choon.
Dharmawardena, A. W.
Fong Weng Senn.
Grassman, Brian Godfrey.
Griffith, Carlos Adrian.
Hasan, Mohammed Mazharuddin.
Joyce, Charles Peter.
Khan, Tousin.
Menzies, James Charles.
Mitra, Bhakta Mohan.
Ng Eng Hean.
Sanmuganathan, Karthigesu.
Sim Bee Teck.
Verwaard, Jan Marinus.
Wainwright, Valentine George Clarence.
Wilkins, Michael Lawrence.

Associate-Membership Examination

Aggarwal, Hari Dev.
Brimer, Alexander.
Clark, Raymond Bostock.
Cuerden, Harold.
Gibson, John Francis.
Goldstein, Anthony Edward.
Hugo, Nocholas Louw.
Iyer, Ramaswami Venkat.
Lang, Ian Rowland.
Lee Hak Kim.
Mokashi, Vasant Shantaram.
Mukerjee, Sachindra Nath.
Pai, Gurpur Ramachandra.
Roussouw, Gabriel Hendrik.
Smith, Kenneth Vivian Hewson.
Snethlage, Frederick.
Stern, Walter Moritz.
Thadani, Bhagwan Nebhraj.
Tsao Li-Chia, Richard.
Venter, Jacobus Johannes.
Verkroost, Johan.
Whitehead, Fernley Sidney.
Yih, Raymond.
Young, Donald George.

EXAMINATIONS, JULY, 1956

The Examinations of the Institution will be held in all centres in the United Kingdom and Overseas on July 17th and 18th, 1956 (Graduateship) and July 19th and 20th (Associate-Membership).

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, May 24th, 1956

Ordinary General Meeting for the election of members, 5.55 p.m.

Annual General Meeting of the Institution, 6 p.m.

Annual General Meeting of Voting Contributors to the Institution of Structural Engineers' Benevolent Fund.

Thursday, June 28th, 1956

Ordinary General Meeting for the election of members, 5.15 p.m.

POST GRADUATE COURSE IN SOIL MECHANICS

The Engineering Department of the University of Manchester announces a Post-Graduate Course in Soil Mechanics to be held from July 9th to July 20th, 1956. The course is intended for engineers whose work involves Soil Mechanics and who wish to study and discuss the latest developments in the subject, and will include recent advances in earth pressure theory, shear strength, stress-strain properties, flexible walls, earth dams, site investigations and field measurements. Design projects of a flexible wall and earth dam will be available together with laboratory demonstrations and limited experiments to suit individual needs.

The fee is £30, inclusive of accommodation and meals.

Further details may be obtained from Professor J. A. L. Matheson, Engineering Department, University of Manchester, Manchester, 13.

EXAMINATIONS

Preparation for the Examinations of the Institution by Attendance at Technical Colleges

A candidate for Graduateship or Associate-Membership may be able to attend a technical college ; these notes are intended to guide him in choosing the most suitable instruction.

Preparation for the Graduateship Examination

Technical Colleges offer :

(a) Full-time courses for degrees or Higher National Diplomas in Building or Engineering,

(b) Part-time day or evening courses for Higher National Certificates in Building or Engineering.

If he obtains a Higher National Certificate or Diploma complying with Appendix II, Section V, of the Regulations Governing Admission to Membership, the candidate will be exempted from the Graduateship Examination.

Alternatively, he may study subjects selected from the available courses and sit the Graduateship Examination. At technical colleges courses are usually available in Building Science or Engineering Science, Strength of Materials, Theory of Structures and Surveying, but students are not normally allowed to select subjects from National Diploma or Certificate courses unless they can show evidence of sound training in more elementary studies. The advice of the College Authorities should be followed.

Preparation for the Associate-Membership Examination

At some technical colleges there are part-time courses in Structural Engineering which cover the syllabus of the Associate-Membership Examination. At other colleges the candidate must rely on Higher National Certificate courses or on advanced courses in Building, Civil Engineering or Municipal Engineering. These cover only part of the requirements for the Associate-Membership Examination.

Colleges in List 'A' provide at least two years of instruction in Theory of Structures and in Structural Engineering Design and Drawing up to Associate-Membership standard. They also give instruction in Structural Specifications, Quantities and Estimates.

List 'A'

Bath Technical College.
Belfast College of Technology.
Birmingham College of Technology.
Bolton Municipal Technical College.
Bradford Technical College.
Bridgend Technical College.
Chesterfield College of Technology.
Coatbridge Technical College, Lanarkshire.

Derby Technical College.
Dudley & Staffordshire Technical College.
Glasgow Royal Technical College.
City of Liverpool College of Building.
L.C.C. Brixton School of Building, S.W.4.
L.C.C. Hammersmith School of Building & Arts & Crafts, W.12.
Manchester College of Technology.
Middlesbrough, Constantine Technical College.
Nottingham & District Technical College.
Salford, Royal Technical College.
S.E. London Technical College, Worsley Bridge Road, S.E.26.
S.W. Essex Technical College, Walthamstow, E.17.
Stafford County Technical College.
Stockport College for Further Education.
Twickenham Technical College.
Willesden Technical College, N.W.10.

Colleges in List 'B' provide instruction in Theory of Structures from which the student may reach Associate-Membership standard, but instruction in Structural Engineering Design and Drawing and in Structural Specifications, Quantities and Estimates is not usually so complete.

List 'B'
Brighton Technical College.
Bristol, The College of Technology.
Cardiff Technical College.
Edinburgh, Heriot-Watt College.
Huddersfield Technical College.
Leeds College of Technology.
London, Battersea Polytechnic, S.W.11.
London, Northampton Polytechnic, E.C.1.
L.C.C. Westminster Technical College, S.W.1.
Newcastle upon Tyne, Rutherford College of Technology.
Plymouth and Devonport Technical College.
Preston, Harris Institute.
Rotherham College of Technology.
Wigan Mining and Technical College.
Woolwich Polytechnic, S.E.18.
West Ham College of Technology.

Students are advised to take the organised courses in Structural Engineering where these are available.

ADDITIONS TO THE LIBRARY

Barber, T. W. *Civil Engineering Design. Notes and Sketches*, 4th Ed., London, 1955.

F.B.I. Register of British Manufacturers, 1956, 28th Ed., London, 1955.

International Cargo Handling Co-ordination Association. Papers of General Conference, 1954, London, 1955.

Knight, H. H. and Knight, R. G. *Builders' Materials*, 3rd Ed., London, 1955.

Low, B. B. *Strength of Materials*, 2nd Ed., London, 1955.

Middleton and Chadwick. *A Treatise on Surveying*, Vols I and II, 6th Ed., London, 1955.

Mills, A. P., Hayward, H. W. and Rader, L. F. *Materials of Construction*, 6th Ed., New York and London, 1955.

Stewart, D. S. *Practical Design of Simple Steel Structures*, Vol. I, 4th Ed., London, 1955.

YEAR BOOK AND LIST OF MEMBERS

The Year Book and List of Members for 1956 will go to press in July, for publication in October, when a copy will be sent to all members.

Members are requested to inform the Secretary of any alterations in titles, degrees or addresses, which have not already been notified, by June 29th, in order that such amendments may be included in the new edition.

LONDON GRADUATES' AND STUDENTS' SECTION

Hon. Secretary : D. E. Capelin, 40, Thornton Crescent, Old Coulsdon, Surrey.

BRANCH NOTICES

LANCASHIRE AND CHESHIRE BRANCH

Joint Hon. Secretaries : J. L. Robinson, A.M.I.Struct.E., 314, Northenden Road, Sale, Manchester ; M. D. Woods, 58, Spring Gardens, Salford.

MIDLAND COUNTIES BRANCH

Hon. Secretary : L. A. Firminger, A.M.I.Struct.E., 190, Green Lanes, Sutton Coldfield, Nr. Birmingham, Warwicks.

MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION

Hon. Secretary : J. E. Jeffries, 18, Radnor Road, Handsworth, Birmingham, 20.

NORTHERN COUNTIES BRANCH

Hon. Secretary : O. Lithgow, A.M.I.Struct.E., 4, Stoneleigh Avenue, Acklam, Middlesbrough.

NORTHERN IRELAND BRANCH

Hon. Secretary : A. H. K. Roberts, B.A., B.A.I., M.I.Struct.E., M.I.C.E.I., "Barbizon," 26, Dunlambert Park, Belfast.

SCOTTISH BRANCH

Hon. Secretary : W. Basil Scott, M.I.Struct.E., 19, Waterloo Street, Glasgow, C.2.

WALES AND MONMOUTHSHIRE BRANCH

The Annual General Meeting will be held at the Mackworth Hotel, Swansea, on Wednesday, 2nd May, 1956, at 6.30 p.m., and will be followed by a short film.

Hon. Secretary : K. J. Stewart, A.M.I.C.E., A.M.I.Struct.E., 15, Glanmor Road, Swansea, Glam.

WESTERN COUNTIES BRANCH

Hon. Secretary : E. Hughes, M.I.Struct.E., 23, Southdown Road, Westbury-on-Trym, Bristol, 9.

YORKSHIRE BRANCH

Hon. Secretary : E. Wrigley, A.M.I.Struct.E., 17, The Drive, Alwoodley, Leeds.

SOUTH WESTERN COUNTIES BRANCH

The Annual General Meeting will be held at the Duke of Cornwall Hotel, Plymouth, on Friday, 18th May, 1956, at 7 p.m.

Joint Hon. Secretaries : E. W. Howells, M.I.Struct.E., 10/12, Market Street, Torquay, Devon ; C. J. Woodrow, J.P., "Elstow," Hartley Park Villas, Tavistock Road, Plymouth.

UNION OF SOUTH AFRICA BRANCH

Hon. Secretary : A. E. Tait, B.Sc., A.M.I.C.E., A.M.I.Struct.E., P.O. Box No. 3306, Johannesburg, South Africa.

During weekdays Mr. Tait can be contacted in the City Engineer's Department, Town Hall, Johannesburg. Phone 34-1111, Ext. 257.

Natal Hon. Secretary : E. G. Bennett, A.M.I.Struct.E., c/o The Reinforcing Steel Co. Ltd., P.O. Box 49, Merebank, Durban.

Cape Section Hon. Secretary : R. Stubbs, M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

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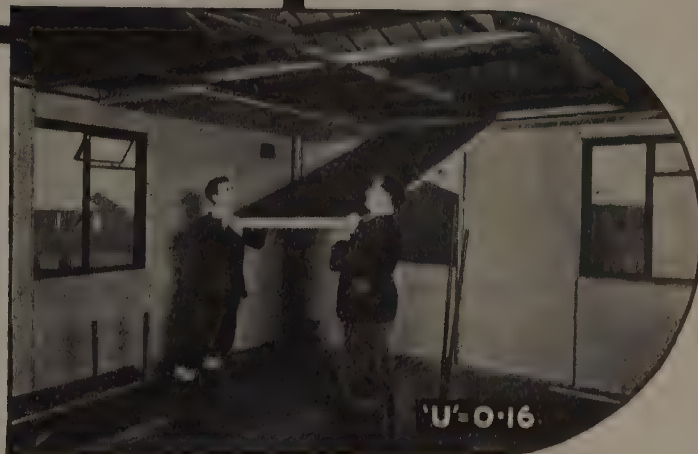

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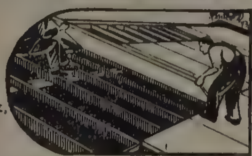

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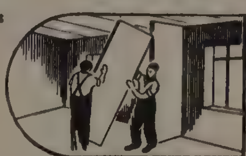

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CLASSIFIED ADVERTISEMENTS

The Publishers regret that owing to the rising cost of production they are reluctantly compelled to increase the charges for Classified Announcements in this Journal.

In future the rate for a run-on classified advertisement will be 8d. per word. The charge for the use of a Box No. will be 3s. 6d.

OFFICIAL APPOINTMENTS

AIR MINISTRY Works Designs Branch requires in London, Structural Engineering Designer/Draughtsmen for reinforced concrete or structural steel work with sound technical training and several years' varied experience in design/detailing of (a) Reinforced concrete construction for all types of buildings or (b) Steel framed sheds, warehouses and similar buildings. Salaries up to £850 p.a., starting pay dependent upon age, quals. and experience. Paid overtime. Long term possibilities with promotion and pensionable prospects. Normally natural born British subjects.—Write, stating age, quals., employment details incl. type of work done, to any Employment Exchange, quoting Order No. Borough 1001.

BRITISH RAILWAYS RESEARCH DEPARTMENT

VACANCIES for Scientific Officers, Grade 1, at Derby. Science degree or professional qualifications and specialised knowledge in one of the following fields : 1. Fatigue properties of materials and mechanical testing (engineering and metallurgical knowledge an advantage) ; 2. Mechanical engineering research (rolling stock, traction problems, bearing design) ; 3. Civil Engineering (2 posts), research on permanent way and associated matters (in this case candidates need not have had previous permanent way experience, but a keen interest in such problems is required). Salary range £965 to £1,065. Superannuation and first class travel facilities. Medical examination.—Applications stating age, qualifications, etc. to Director of Research, British Transport Commission, British Railways Division, 222, Marylebone Road, London, N.W.1

LONDON COUNTY COUNCIL. Architect's Department. Applications are invited from persons who have successfully completed a course of study which is recognised by the Institution of Civil Engineers as exempting them from Final Parts I and II of the Institution's examination and who are prepared to serve for two years under agreement in the Structural Engineering Division in order to complete their practical training as required by the Institution of Civil Engineers. Candidates must be not more than 25 years of age. The starting salary will be in the scale £620-817. There are two vacancies.—Application forms, returnable by 16th April, 1956, from The Architect (AR/EK/GSE/3), County Hall, S.E.1 (519).

LONDON COUNTY COUNCIL—Architect's Department. As a result of regrading of positions and salary increases, there are opportunities in the Architect's Department for Structural Engineers : Grade II (£987—£1,184) ; Grade III (£775—£987) ; and Assistants (£620—£818). There is a full programme of interesting work. Promotion is by merit. Starting points in the various scales may be according to qualifications and experience. The department is able to offer experience of the highest value and, to those interested, good prospects of a permanent career in the public service. (1) Structural Engineering Division : A few good designers required at Grade II level, also engineers Grade III and a few resident engineers Grade III. Vacancies for a number of engineering assistants. (2) District Surveyors' Service : Vacancies for Structural Engineers at Grade II, Grade III and assistant level.—Application forms and further information obtainable from The Architect (AR/EK/DSE/1), County Hall, S.E.1. (385).

LONDON COUNTY COUNCIL. Architect's Department. Vacancies for Engineering Assistants (up to £818) and Engineer Grade III (up to £987) in the Structural Engineering Division. Work includes steelwork and reinforced concrete design and detailing for Council's buildings.—Particulars and application forms from Architect (AR/EK/SE/2), The County Hall, S.E.1 (1278).

STRUCTURAL Engineers urgently required. (a) Senior Assistant experienced in design of steelwork for buildings. Must be A.M.I.Struct.E. or equivalent. Salary APT.V.—£795—£970 or APT. VI. £880—£1,080. (b) Assistants experienced in detailing of steelwork for buildings, educational standard Graduate Inst. Structural Engineers or equivalent. Salary APT. IV. £710—£885. Alternate Saturdays free, canteen facilities.—Application forms may be obtained from the County Architect, Bishopgarth, Westfield Road, Wakefield, and should be returned within ten days of the publication of this advertisement.

CLASSIFIED ADVERTISEMENTS

The engagement of persons answering these advertisements must be made through a Local office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment is excepted from the provisions of the Notification of Vacancies Order, 1952.

SITUATIONS VACANT

AN excellent opportunity for Senior and Junior Reinforced Concrete Designer/Detailers in Victoria Consulting Engineer's Office, specialising in heavy industrial and Civil Engineering projects—five day week and excellent working conditions. Salary, bonus, promotion commensurate with ability. Box No. 0709. STRUCTURAL ENGINEERS, 43a, Streatham Hill, S.W.2.

ASSISTANT Structural Engineers required by London Consulting Engineers. Good mathematical ability and experience of structural steel design essential. Five-day week. Pension scheme. Luncheon and recreation clubs. Salary according to qualification and experience.—Apply with full particulars of age, qualifications and experience to Box No. 9804, c/o Charles Barker & Sons Ltd., 31, Budge Row, London, E.C.4.

CIVIL Engineering, Architectural and Building Engineers and Draughtsmen required to work in Manchester by well-known firm of Consulting Engineers, in connection with Civil engineering and building aspects of large Thermal and Nuclear Electricity Generating Stations. Previous experience in the nuclear field is not expected—arrangements will be made for the appropriate training where necessary. Salary dependent on age and qualifications.—Reply in writing for application form to Kennedy & Donkin, 64, Royal Exchange, Manchester, 2.

CHIEF Draughtsman required by firm engaged in design of Reinforced Concrete and supply and fixing of Steel Reinforcement, to take charge of rapidly expanding drawing office near Victoria Station. Applicants must have had similar experience, and preferably have some commercial knowledge. Very good prospects for right man. Five-day week, pension scheme, etc. — Write stating age, experience and salary required to Box No. 0712, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

DESIGNERS and Detailers with experience required by Consulting Civil and Structural Engineers for steel and reinforced concrete projects. Good working conditions with interesting and varied work. Salary in range £600 to £1,000 according to qualifications and experience.—Applications stating age, qualifications, experience and salary required to Box No. 0711, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

DESIGNER Structural Steelwork (A.M.I.Struct.E. or equivalent) required for senior position in a firm already leaders in the design and fabrication of rigid frame buildings. The successful candidate will be responsible for developing, in conjunction with a director, an independent branch of the firm already established at Burton-on-Trent. Ability to deal direct with clients, some administrative background and plenty of drive are essential qualifications. Age 25 to 35. Salary at least £1,000 per annum plus a share of profits. Assistance given with accommodation. —Conder Engineering Co. Ltd., Winchester. Telephone Winchester 5095.

DRAUGHTSMAN required by Consulting Engineers, Westminster for reinforced concrete bridge work. Salary up to £800 per annum according to ability. Interesting work and excellent prospects. This year's holiday arrangements honoured.—Write stating age and details of experience, Box No. 0714, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

IMPERIAL CHEMICAL INDUSTRIES LIMITED, Dyestuffs Division, has vacancies at Manchester for Civil and Structural Engineering Draughtsmen for design and detail work in connection with new projects for the manufacture of synthetic fibre forming materials and other organic chemicals. Basic minimum qualification required is H.N.C.—Applications with brief details of experience and qualifications should be made to the Staff Department, Hexagon House, Blackley, Manchester, 9.

J. MOWLEM & CO. LTD. have vacancies in their Concrete Laboratory for a Concrete Engineer and an Assistant Concrete Engineer. These vacancies are permanent and form an excellent opportunity for the right type of man. Salary according to age and experience. For the junior position previous experience in this type of work is not essential as adequate training will be given.—Apply giving all details in own handwriting to Box No. 0707, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

CLASSIFIED ADVERTISEMENTS—continued

JENKINS & POTTER, 66, Victoria Street, S.W.1 require one Senior and one Junior Assistant experienced in reinforced concrete. Five-day week, salary £600-£1,200.—Telephone Tate Gallery 9333 for appointment.

PART-TIME assistance required by Westminster Consultants for detailing of concrete bridges. Liberal remuneration for experienced Structural Draughtsman.—Write in confidence stating age and details of experience. Box No. 0713, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

REINFORCED Concrete Designer Draughtsman required by consultants. Salary £850 to £950 per annum. Apply Atkinson & Partners, Elm Grove, Berkhamsted, Herts.

REINFORCED Concrete Designers and Draughtsmen required for varied and interesting work for heavy foundation and structural contracts. Permanent positions with opportunities for advancement. Good salary and entry into superannuation scheme may be arranged after twelve months' service. Applicants should write stating age, qualifications and experience to Mitchell Construction Company, Wharf Works, Peterborough.

REINFORCED Concrete Detailer required for Site outside London area.—Write stating age, experience, salary required to Bylander & Waddell, 26, Old Burlington Street, London, W.1.

REINFORCED Concrete, S. Rhodesia. Qualified B.Sc. or A.M.I Struct.E. Engineers with minimum three years design and detailing experience required by leading Structural and Consulting Firm in Salisbury for a most varied range of Reinforced concrete structures. Knowledge of Structural Steelwork a recommendation. Position permanent, good conditions, pension, leave, travelling expenses refunded.—Write stating age, experience etc. to Lysaght & Co. (Pvt.) Ltd., P.O. Box 205, Salisbury, S. Rhodesia.

REINFORCED Concrete Draughtsmen required in Civil Engineering Dept. of the Coppee Co. (G.B.) Ltd., 140, Piccadilly, London, W.1. Colliery structures of interesting and varied character. Some experience necessary and knowledge of design advantageous. Staff Pension Scheme. Five-day week.

REINFORCED Concrete Designer Detailer required by Consulting Engineers. Commencing salary £850—£950 according to experience. Five-day week, pension scheme, modern office in Central London.—Reply Box No. 0693, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

SENIOR Reinforced Concrete Designers wanted for leading R.C. Engineers and Contractors. Must be fully conversant with Code of Practice, L.C.C. Bye-Laws, and able to design light framed structures from estimating stage to final details. Five-day week. Pension scheme. Progressive position. Starting salary from £900 upwards according to ability. This year's holiday arrangements honoured. Juniors also required, similar conditions.—Write Box No. 0627, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

STRUCTURAL Engineer fully experienced in the design of reinforced concrete structures of all types, required by Consulting Engineers. Five-day week, pension scheme, new and modern office in Central London. Commencing salary £1,250 p.a. —Reply Box No. 0692, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

STRUCTURAL Steelwork. First class Designers required conversant with L.C.C. Bye-Laws and B.S.S.449.—Reply giving age, qualifications, experience and salary required to Chief Designer, Redpath Brown & Co. Ltd., 3, Duncannon Street, W.C.2.

STRUCTURAL steel and/or reinforced concrete designers and detailers required by London Consulting Engineers. 5 day week; Luncheon vouchers: Pension Scheme. Travelling expenses paid for interview. Bylander & Waddell, 26, Old Burlington Street, London, W.1.

TAYLOR WOODROW CONSTRUCTION Limited invite applications from Structural Engineers and Draughtsmen for work in connection with the design and construction of Atomic Power Stations. Excellent opportunities are offered in this important field and the posts, which are pensionable, carry good salaries. Applicants, who should have experience in reinforced concrete design, should write to Mr. D. A. J. Ballinger at Queens House, Kingsway, London, W.C.2.

TWISTEEL Reinforcement Limited have vacancies for Designers and Detailers in their London Drawing Offices.—Apply, stating experience to 43, Upper Grosvenor Street, W.1.

'TWISTEEL' REINFORCEMENT Limited have vacancies in their Birmingham and Glasgow Drawing Offices for Reinforced Concrete Designers and Detailers. Five-day week. Pension Scheme. Lunching facilities.—Apply in writing stating experience and salary required to Chief Engineer at either Alma Street, Smethwick, 40, Staffs, or 19 St. Vincent Place, Glasgow, C.1.

CLASSIFIED ADVERTISEMENTS—continued.

WANTED—Structural Steel Engineers able to detail, estimate, etc. Five-day week; opportunity to travel widely. £16 per week to start. Great scope.—Write Bellman Hangars Ltd., Hobart House, Grosvenor Place, Victoria, S.W.1.

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LATTICE Steel Erection Masts (light and heavy), 30 ft. to 150 ft. high for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1. ('Phone: SLOane 5259.)

INDEX TO ADVERTISERS

NOTICE

THIS VOLUME IS INCOMPLETE

THE FOLLOWING ISSUES ARE ON ORDER:

Vol.34	No.6-12	1956
Vol.35	No.1-9	1957